



# NONRESIDENT TRAINING COURSE



September 1997

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# Information Systems Technician Training Series

## Module 4—Communications Hardware

NAVEDTRA 14225

### NOTICE

Any reference within this module to “Radioman” or the former “Radioman rating” should be changed to “Information Systems Technician” and the “Information Systems Technician (IT) rating”. The subject matter presented relates to the occupational standards for the IT rating.

**Although the words “he,” “him,” and “his” are used sparingly in this course to enhance communication, they are not intended to be gender driven or to affront or discriminate against anyone.**

## PREFACE

By enrolling in this self-study course, you have demonstrated a desire to improve yourself and the Navy. Remember, however, this self-study course is only one part of the total Navy training program. Practical experience, schools, selected reading, and your desire to succeed are also necessary to successfully round out a fully meaningful training program.

**COURSE OVERVIEW:** In completing this nonresident training course, you will demonstrate a knowledge of the subject matter by correctly answering questions on the following subjects: Communications Hardware, and Satellites and Antennas.

**THE COURSE:** This self-study course is organized into subject matter areas, each containing learning objectives to help you determine what you should learn along with text and illustrations to help you understand the information. The subject matter reflects day-to-day requirements and experiences of personnel in the rating or skill area. It also reflects guidance provided by Enlisted Community Managers (ECMs) and other senior personnel, technical references, instructions, etc., and either the occupational or naval standards, which are listed in the *Manual of Navy Enlisted Manpower Personnel Classifications and Occupational Standards*, NAVPERS 18068.

**THE QUESTIONS:** The questions that appear in this course are designed to help you understand the material in the text.

**VALUE:** In completing this course, you will improve your military and professional knowledge. Importantly, it can also help you study for the Navy-wide advancement in rate examination. If you are studying and discover a reference in the text to another publication for further information, look it up.

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## **Sailor's Creed**

“I am a United States Sailor.

I will support and defend the Constitution of the United States of America and I will obey the orders of those appointed over me.

I represent the fighting spirit of the Navy and those who have gone before me to defend freedom and democracy around the world.

I proudly serve my country's Navy combat team with honor, courage and commitment.

I am committed to excellence and the fair treatment of all.”

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# **SUMMARY OF THE RADIOMAN TRAINING SERIES**

## **MODULE 1**

Administration and Security—This module covers Radioman duties relating to administering AIS and communication systems. Procedures and guidance for handling of classified information, messages, COMSEC material and equipment, and AIS requirements are discussed.

## **MODULE 2**

Computer Systems—This module covers computer hardware startup, including peripheral operations and system modification. Other topics discussed include computer center operations, media library functions, system operations, and troubleshooting techniques. Data file processes, memory requirements, and database management are also covered.

## **MODULE 3**

Network Communications—This module covers network administration, LAN hardware, and network troubleshooting. Related areas discussed are network configuration and operations, components and connections, and communication lines and nodes.

## **MODULE 4**

Communications Hardware—This module covers various types of communications equipment, including satellites and antennas. Subjects discussed include hardware setup procedures, COMSEC equipment requirements, distress communications equipment, troubleshooting equipment, satellite theory, and antenna selection and positioning.

## **MODULE 5**

Communications Center Operations—This module covers center operations, including transmit message systems, voice communications, center administration, quality control, and circuit setup/restorations. Guidelines for setting EMCON and HERO conditions and cryptosecurity requirements are also discussed.

# INSTRUCTIONS FOR TAKING THE COURSE

## ASSIGNMENTS

The text pages that you are to study are listed at the beginning of each assignment. Study these pages carefully before attempting to answer the questions. Pay close attention to tables and illustrations and read the learning objectives. The learning objectives state what you should be able to do after studying the material. Answering the questions correctly helps you accomplish the objectives.

## SELECTING YOUR ANSWERS

Read each question carefully, then select the BEST answer. You may refer freely to the text. The answers must be the result of your own work and decisions. You are prohibited from referring to or copying the answers of others and from giving answers to anyone else taking the course.

## SUBMITTING YOUR ASSIGNMENTS

To have your assignments graded, you must be enrolled in the course with the Nonresident Training Course Administration Branch at the Naval Education and Training Professional Development and Technology Center (NETPDTC). Following enrollment, there are two ways of having your assignments graded: (1) use the Internet to submit your assignments as you complete them, or (2) send all the assignments at one time by mail to NETPDTC.

**Grading on the Internet:** Advantages to Internet grading are:

- you may submit your answers as soon as you complete an assignment, and
- you get your results faster; usually by the next working day (approximately 24 hours).

In addition to receiving grade results for each assignment, you will receive course completion confirmation once you have completed all the

assignments. To submit your assignment answers via the Internet, go to:

**<http://courses.cnet.navy.mil>**

**Grading by Mail:** When you submit answer sheets by mail, send all of your assignments at one time. Do NOT submit individual answer sheets for grading. Mail all of your assignments in an envelope, which you either provide yourself or obtain from your nearest Educational Services Officer (ESO). Submit answer sheets to:

COMMANDING OFFICER  
NETPDTC N331  
6490 SAUFLEY FIELD ROAD  
PENSACOLA FL 32559-5000

**Answer Sheets:** All courses include one “scannable” answer sheet for each assignment. These answer sheets are preprinted with your SSN, name, assignment number, and course number. Explanations for completing the answer sheets are on the answer sheet.

**Do not use answer sheet reproductions:** Use only the original answer sheets that we provide—reproductions will not work with our scanning equipment and cannot be processed.

Follow the instructions for marking your answers on the answer sheet. Be sure that blocks 1, 2, and 3 are filled in correctly. This information is necessary for your course to be properly processed and for you to receive credit for your work.

## COMPLETION TIME

Courses must be completed within 12 months from the date of enrollment. This includes time required to resubmit failed assignments.

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If your overall course score is 3.2 or higher, you will pass the course and will not be required to resubmit assignments. Once your assignments have been graded you will receive course completion confirmation.

If you receive less than a 3.2 on any assignment and your overall course score is below 3.2, you will be given the opportunity to resubmit failed assignments. **You may resubmit failed assignments only once.** Internet students will receive notification when they have failed an assignment--they may then resubmit failed assignments on the web site. Internet students may view and print results for failed assignments from the web site. Students who submit by mail will receive a failing result letter and a new answer sheet for resubmission of each failed assignment.

## **COMPLETION CONFIRMATION**

After successfully completing this course, you will receive a letter of completion.

## **ERRATA**

Errata are used to correct minor errors or delete obsolete information in a course. Errata may also be used to provide instructions to the student. If a course has an errata, it will be included as the first page(s) after the front cover. Errata for all courses can be accessed and viewed/downloaded at:

<http://www.advancement.cnet.navy.mil>

## **STUDENT FEEDBACK QUESTIONS**

We value your suggestions, questions, and criticisms on our courses. If you would like to communicate with us regarding this course, we encourage you, if possible, to use e-mail. If you write or fax, please use a copy of the Student Comment form that follows this page.

## **For subject matter questions:**

E-mail: n311.products@cnet.navy.mil  
Phone: Comm: (850) 452-1501  
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Comm: (850) 452-1511/1181/1859  
DSN: 922-1511/1181/1859  
FAX: (850) 452-1370  
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## **NAVAL RESERVE RETIREMENT CREDIT**

If you are a member of the Naval Reserve, you may earn retirement points for successfully completing this course, if authorized under current directives governing retirement of Naval Reserve personnel. For Naval Reserve retirement, this course is evaluated at 3 points. (Refer to *Administrative Procedures for Naval Reservists on Inactive Duty*, BUPERSINST 1001.39, for more information about retirement points.)



## Student Comments

**Course Title:** *Information Systems Technician Training Series*  
*Module 4—Communications Hardware*

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**NAVEDTRA:** 14225 **Date:** \_\_\_\_\_

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**Your comments, suggestions, etc.:**

<p><b>Privacy Act Statement:</b> Under authority of Title 5, USC 301, information regarding your military status is requested in processing your comments and in preparing a reply. This information will not be divulged without written authorization to anyone other than those within DOD for official use in determining performance.</p>
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NETPDTC 1550/41 (Rev 4-00)



# CHAPTER 1

## COMMUNICATIONS HARDWARE

### LEARNING OBJECTIVES

*Upon completing this chapter, you should be able to do the following:*

- *Determine the equipment required for each communications system.*
  - *Identify the hardware setup procedures for radio systems.*
  - *Identify the use of COMMSPTS.*
  - *Identify procedures and requirements for communications equipment as it pertains to OTAR/OTAT functions.*
  - *Determine utilization, frequencies and watches needed for distress communication equipment.*
  - *Interpret how to monitor circuit quality equipment.*
- 

The high-paced operations required of modern fleet units demand communication systems that are capable of providing high-speed, accurate, and secure transmission and reception of intelligence. To keep pace with the ever-increasing complexity of operations, today's communication systems are necessarily highly sophisticated and versatile. For our ships and submarines to operate effectively, whether independently or as part of a battle group, they must have communication systems and operators that are capable of meeting this challenge.

In this chapter, we will discuss various aspects of fleet communication systems. As a Radioman, you will be responsible for knowing the different communication systems used by the Navy and what communication equipments make up a system.

### COMMUNICATIONS SYSTEMS

Through equipment design and installation, many equipments are compatible with each other and can be used to accomplish various functions. Using this design concept, nearly all the communication needs of a ship can be met with fewer pieces of communications equipment than were previously required.

Communications can be maintained at the highest possible state of readiness when all levels of command understand the capabilities and limitations of the systems. Many communications failures are attributable to poor administration rather than to equipment failure or technical problems.

In this section, we will discuss predeployment readiness; low-, high-, very-high-, ultra-high-, and super-high-frequency communications systems; and equipment components that comprise these systems.

### UNDERWAY PREPARATION

Ships deploying to overseas areas must be in a state of maximum operational and communications readiness. Type commanders determine the level of readiness of deploying ships and ensure they are adequately prepared.

A check-off list is an excellent method to ensure that step-by-step preparations are completed prior to a deployment. This list should cover all aspects of communications readiness and should begin well in advance of the underway period. Some of the points to be checked include scheduling of communications assistance team (CAT) visits, maintenance and

operational checks of equipment and antennas, and consumable supply levels.

The *Basic Operational Communications Doctrine (U)*, NWP 4 (NWP 6-01), provides suggested minimum check-off sheets, including a **predeployment check-off sheet** and a **preunderway check-off sheet**. The first sheet provides a timetable of required checks and objectives. The second sheet is tailored to individual ships and unique requirements.

### LOW-FREQUENCY SYSTEMS

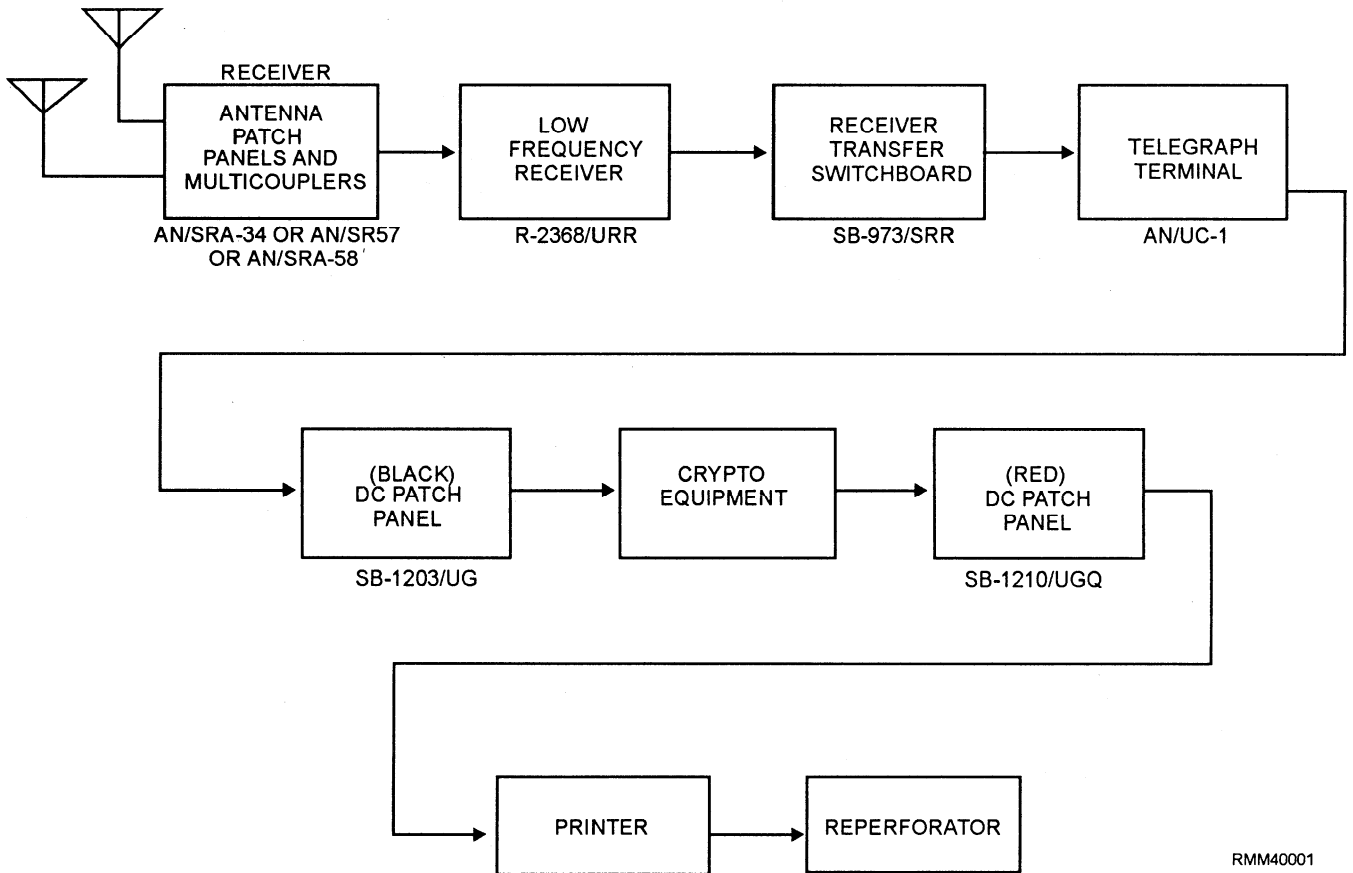
The low-frequency (LF) band (30-300 kHz) is used for long-range direction finding, medium- and long-range communications, aeronautical radio navigation, and submarine communications.

A low-frequency transmitter, such as the AN/FRT-72, is used to transmit a high-powered signal over long distances. Low-frequency transmitters are normally used only at shore stations or for special applications.

The low-frequency receive system is designed to receive low-frequency broadcast signals and to reproduce the transmitted intelligence. A typical low-

frequency receive system is shown in figure 1-1. Refer to the equipments in the figure as you study the next section.

1. **Antennas**— The low-frequency signal is received by the antennas, which are connected to the receiver antenna patch panels and multicouplers (AN/SRA-34, AN/SRA-57, or AN/SRA-58). Multicouplers and patch panels allow the operator to select different antennas and connect them to different receivers. This way, an operator can select the correct combination suited for a particular system.
2. **LF Receiver**— The output of the receiver (audio) is fed to the receiver transfer switchboard.
3. **Switchboard**— The switchboard can connect the receiver output to numerous pieces of equipment. In figure 1-1, the receiver output is connected to the AN/UCC-1 Teleprinter Terminal (discussed later).
4. **AN/UCC-1**— The AN/UCC-1, as a converter comparator, converts the received audio signal



RMM40001

Figure 1-1.—Low-frequency receive system.

(AF) to direct current (dc) for use by the teleprinter equipment.

5. **Black dc Patch Panel**— The dc output of the AN/UCC-1 is fed to the SB-1203/UG DC Patch Panel. The dc patch panel permits the signal to be patched to any cryptoequipment (discussed later) desired.
6. **Cryptoequipment**— The cryptoequipment decrypts the signal and connects its output to the red SB-1210/UGQ DC Patch Panel.
7. **Red dc Patch Panel**— The SB-1210/UGQ can be patched to a selected printer that prints the signal in plain readable text.

## HIGH-FREQUENCY SYSTEMS

The high-frequency (HF) band (3-30 MHz) is primarily used by mobile and maritime units. The military uses this band for long-range voice and teleprinter communications. This band is also used as a backup system for the satellite communications system. We will discuss satellite communications later in this chapter.

Figure 1-2 shows a typical high-frequency transmit system. In transmitting teleprinter information, the equipments shown in figure 1-2 perform the same functions as the equipments shown in figure 1-1, except the equipments in the high-frequency system do the functions in reverse order.

In the HF transmit system, the AN/UCC-1 Telegraph Terminal converts dc signals into audio tone signals. The output of the AN/UCC-1 is connected to the transmitter transfer switchboard. The C-1004 Transmit Keying and Receive Control/Teleprinter is used to key the transmitter during teleprinter operations.

Voice communications from some remote locations are also connected to the transmitter transfer switchboard. Voice communications are initiated at a handset (remote phone unit) and connected to the C-1138 Radio Set Control. The output of the radio set control is connected to the transmitter transfer switchboard. The transmitter transfer switchboard permits the operator to select the proper transmitter for the frequency to be transmitted.

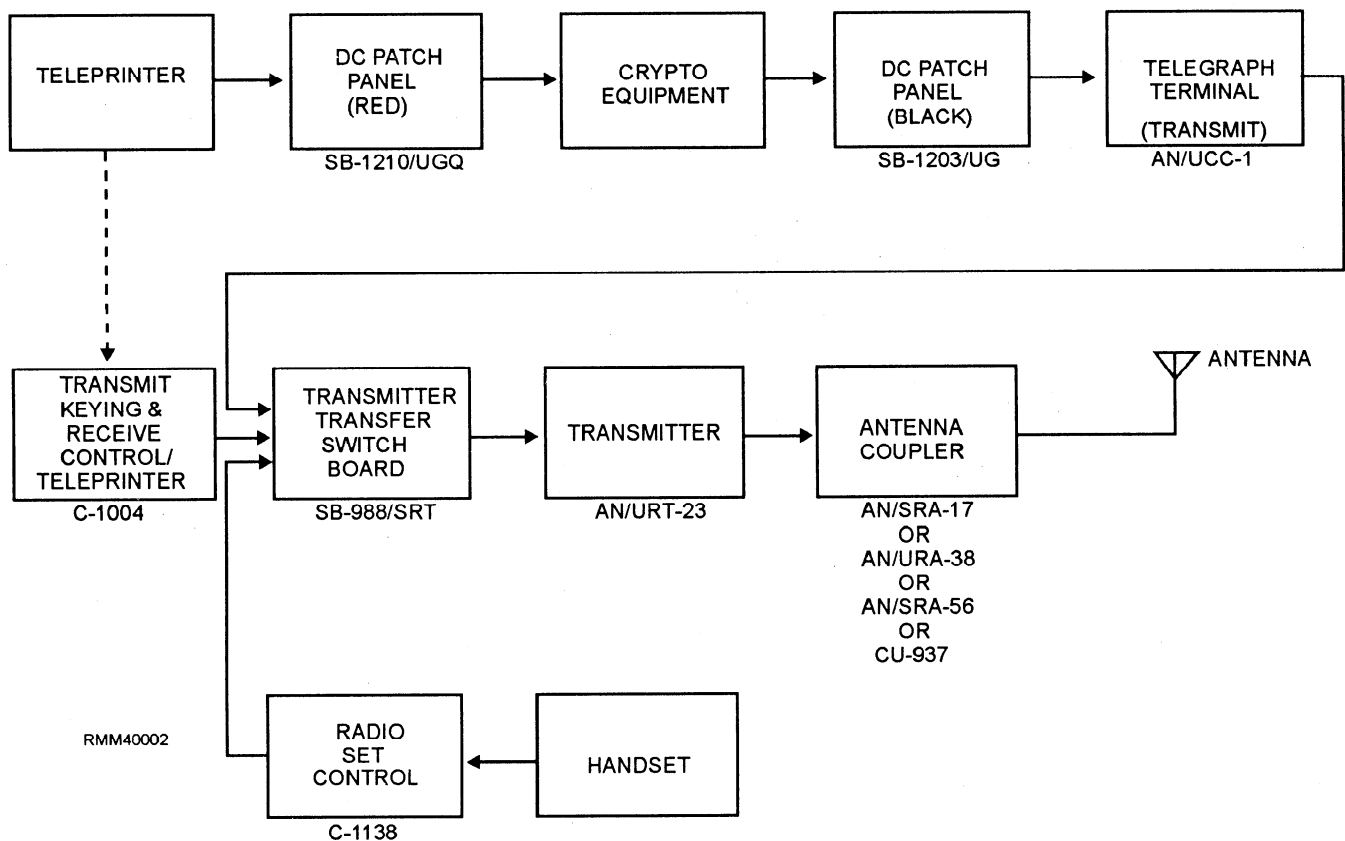


Figure 1-2.—High-frequency transmit system.

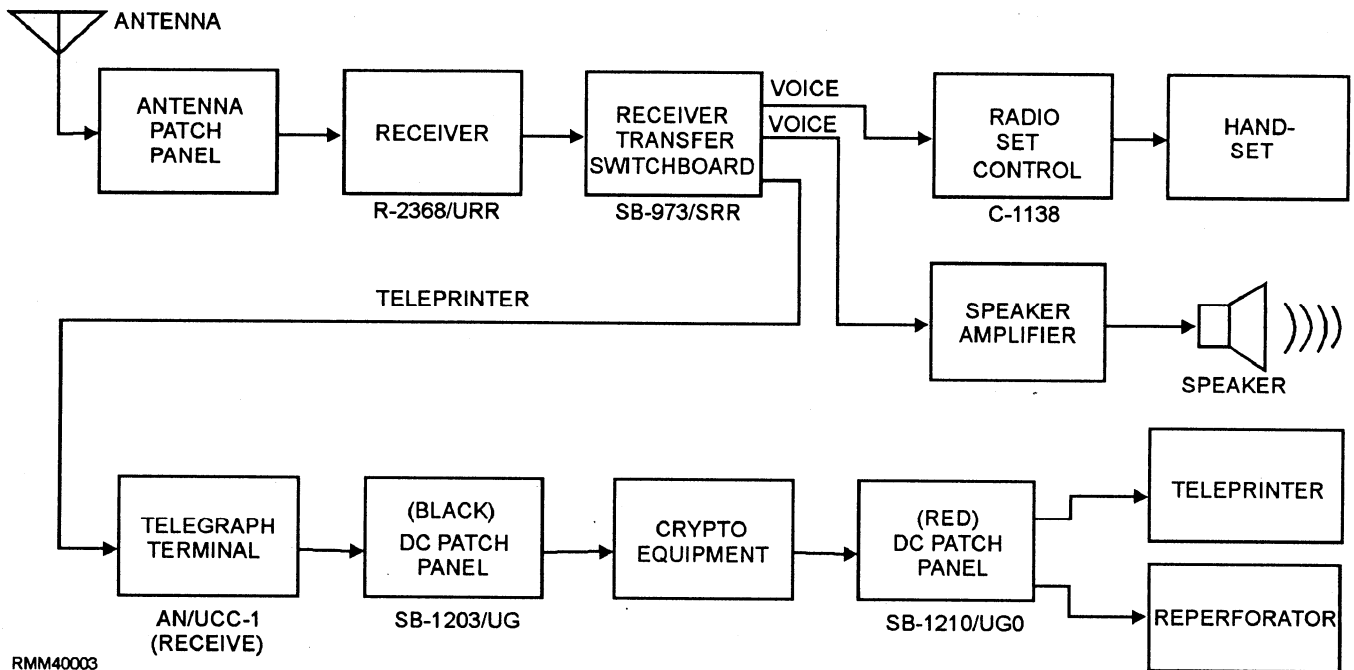


Figure 1-3.—High-frequency receive system.

Figure 1-3 shows atypical high-frequency receive system. Refer to the figure as we follow the signal path through the system.

1. A transmitted high-frequency signal is received by the antenna, which converts electromagnetic energy to electrical energy.
2. The signal travels through a transmission line to an antenna patch panel, where it can be distributed to any of a number of receivers.
3. The receiver converts the RF signal into a teleprinter or voice signal, depending upon what is desired.
4. The output of the receiver is then sent to the receiver transfer switchboard.
5. If a teleprinter signal was selected, the teleprinter signal from the switchboard goes to the AN/UCC-1 and then follows the same path as we described in the low-frequency receive section. Identical pieces of equipment are used, and they perform the same functions.
6. If a voice signal was selected, the voice signal from the receiver transfer switchboard is sent to the radio set control. The output is then sent to a handset. The voice signal can also be sent from the switchboard to a remote speaker amplifier. There, it can be placed on a speaker so that the

user can listen to the received signal without holding onto the handset.

### VERY-HIGH-FREQUENCY SYSTEMS

The very-high-frequency (VHF) band (30-300 MHz) is used for aeronautical radio navigation and communications, radar, amateur radio, and mobile communications (such as for boat crews and landing parties). Figure 1-4 shows a basic block diagram of a

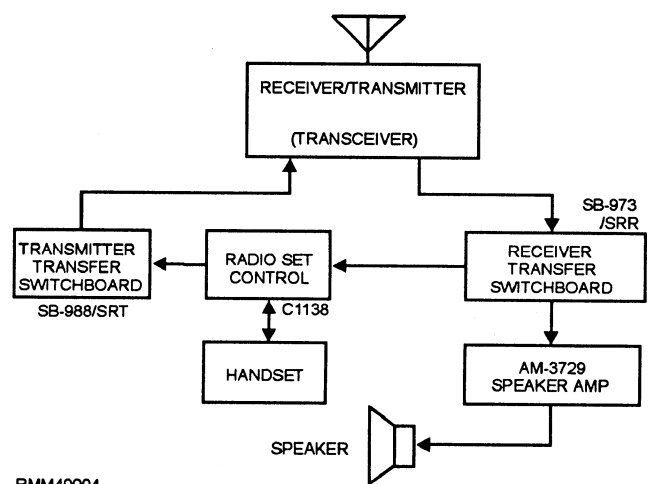


Figure 1-4.—Very-high-frequency transmit and receive system.

VHF transmit and receive system using a transceiver. Although a transceiver is used in this system, the transmit and receive systems are described separately. Refer to figure 1-4 as we follow the signal path on the transmit side of the system.

On the transmit side of the system, the operator, at a remote location:

1. Talks into the handset.
2. The handset is connected to the C-1138 Radio Set Control.
3. The output of the radio set control is sent to the transmitter transfer switchboard.
4. The output of the switchboard is sent to the transmit side of the transceiver.
5. The transceiver converts the input signal to an RF signal for radiation by the antenna.

Continue to refer to figure 1-4 as we follow the path of the incoming signal.

1. The incoming signal in figure 1-4 is received by the antenna.
2. This signal is sent to the receive side of the transceiver.
3. The output of the transceiver is sent to the receiver transfer switchboard.
4. From the receiver transfer switchboard, the output is sent to either the C-1138 Radio Set Control or to a speaker amplifier, or both, depending on the preference of the user.
5. The output of the radio set control is sent to a handset.

6. A speaker receives the output of the speaker amplifier.

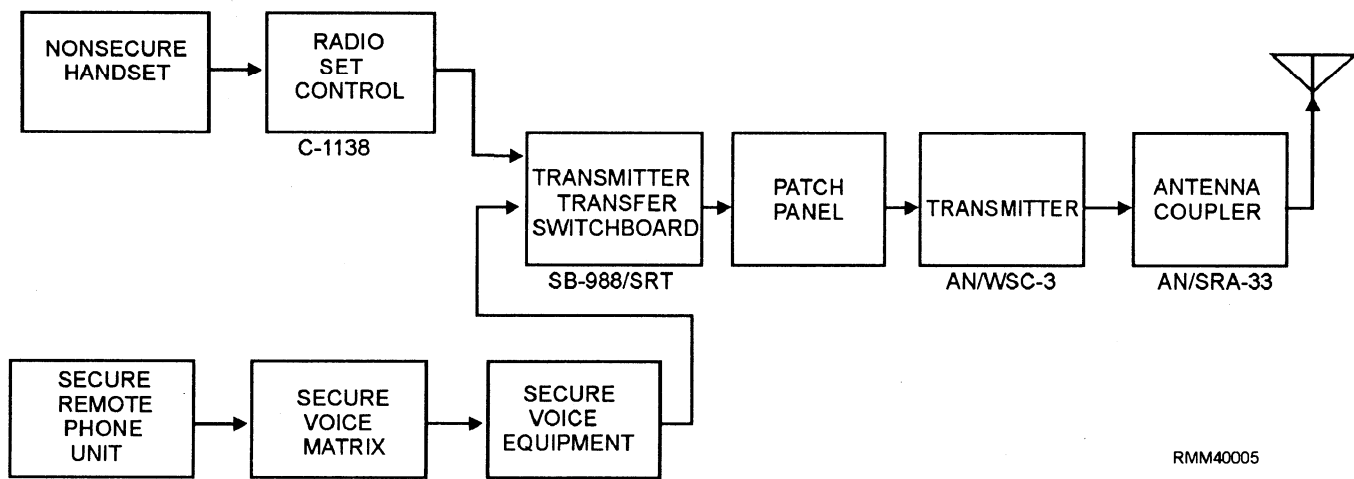
## ULTRA-HIGH-FREQUENCY SYSTEMS

The ultra-high-frequency (UHF) band (300-MHz to 3-GHz) is used for line-of-sight (short-range) communications. The term “line of sight,” as used in communications, means that both transmitting and receiving antennas must be within sight of each other and unaffected by the curvature of the Earth for proper communications operation.

The UHF band is also used for satellite communications. Although satellite communications are line of sight, the distance the signal travels is much greater than that of UHF surface communications, because the antennas remain in sight of each other.

As in the VHF section, the transmit and receive systems will be described separately. Figure 1-5 shows a basic block diagram of a UHF transmit system, which uses a transceiver.

1. On the transmit side of the nonsecure voice system, the operator at a remote location talks into the handset. The handset is connected to the C-1138 Radio Set Control.
2. The C-1138 is connected to the transmitter transfer switchboard, where it is patched to the transmitter.
3. The operator at a remote location talks into the secure voice remote phone unit (RPU).
4. The RPU is connected to the secure voice matrix. This is the tie point for connecting more than one RPU. The output of the matrix is



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Figure 1-5.—Ultra-high-frequency transmit system.

connected to the secure voice equipment, which encrypts the information received.

5. The output of the secure voice equipment is connected to the transmitter transfer switchboard.
6. The transmitter transfer switchboard is used to connect numerous RPUs to any number of transmitters.
7. The output of the patch panel is connected to the transmitter side of the transceiver, which, in turn, is connected to an antenna coupler.

Figure 1-6 shows a basic diagram of a UHF receive system. We will next follow the UHF signal path through the receive side of the system.

1. The received signal is picked up by the antenna and connected to the receiver side of the transceiver through the antenna coupler.
2. The output of the receiver is connected to the receiver transfer switchboard. From here, it can be connected to either the nonsecure or the secure voice systems, depending upon the mode of transmission.
3. When a nonsecure signal is received, the output of the receiver transfer switchboard can be connected to the radio set control or a speaker amplifier, or both, depending on the preference of the user.
4. The output of the radio set control is connected to a handset, whereas the output of the speaker amplifier is connected to a speaker.
5. If a secure voice transmission is received, the output of the receiver transfer switchboard is

connected to the secure voice equipment, where it is decrypted.

6. The secure voice equipment output is connected to the secure voice matrix. The secure voice matrix performs the same function as the matrix on the transmit system.
7. The secure voice matrix output is connected to the secure remote phone unit. Here, the signal is converted back to its original form.

## SUPER-HIGH-FREQUENCY SYSTEMS

The super-high-frequency (SHF) band (3-30 GHz) is strictly for line-of-sight communications. It is configured much the same as the UHF system. SHF is mainly used for satellite communications.

SHF satellite communications is a high-volume system that offers reliable tactical and strategic communications services to U.S. Navy elements ashore and afloat. The system is composed of the terminal segment, consisting of U.S. Navy-operated Earth terminals and mobile terminals. It also includes a portion of the Defense Satellite Communications System (DSCS) satellite segment. *Navy Super High Frequency Satellite Communications*, NTP 2, Section 1 (C), provides comprehensive coverage of the Navy SHF satellite system.

## PATCH PANELS

Teleprinter patch panels are used for the interconnection and transfer of teleprinter signals aboard ship. In the previous block diagrams two patch panels, one labeled red, the other black, were shown. These are the teleprinter patch panels SB-1210/UG and

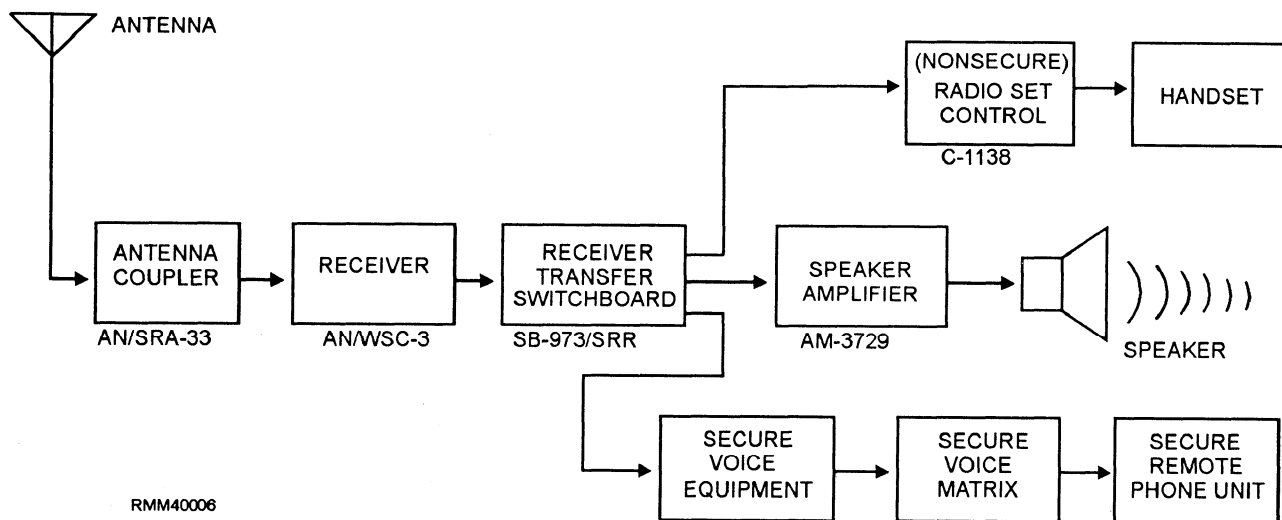


Figure 1-6.—Ultra-high-frequency receive system.



SB-1203/UGQ (figure 1-7). The SB-1210/UG is intended for use with cryptographic devices; the SB-1203/UGQ is a general-purpose panel.

The patch panels are red or black to identify secure and nonsecure information. Red indicates that secure (classified) information is being passed through the panel. Black indicates that nonsecure (unclassified) information is being passed through the panel.

Both panels are also labeled with signs. The red panel sign has 1-inch-high white block letters that read "RED PATCH PANEL." The black panel normally has two black signs containing 1-inch-high white block letters. One sign reads "BLACK PATCH PANEL" and the other, "UNCLAS ONLY."

Each panel contains six channels. Each channel has its own series circuit of looping jacks, set jacks, and a rheostat for adjusting line current. The number of looping and set jacks in each channel varies with the panel model. Each panel includes a meter and rotary selector switch for measuring the line current in any channel.

Six miscellaneous jacks are contained in each panel. Any teleprinter equipment not regularly assigned to a channel maybe connected to one of these jacks. In some instances, commonly used combinations of equipment are permanently wired together within the panel (called *normal-through*).

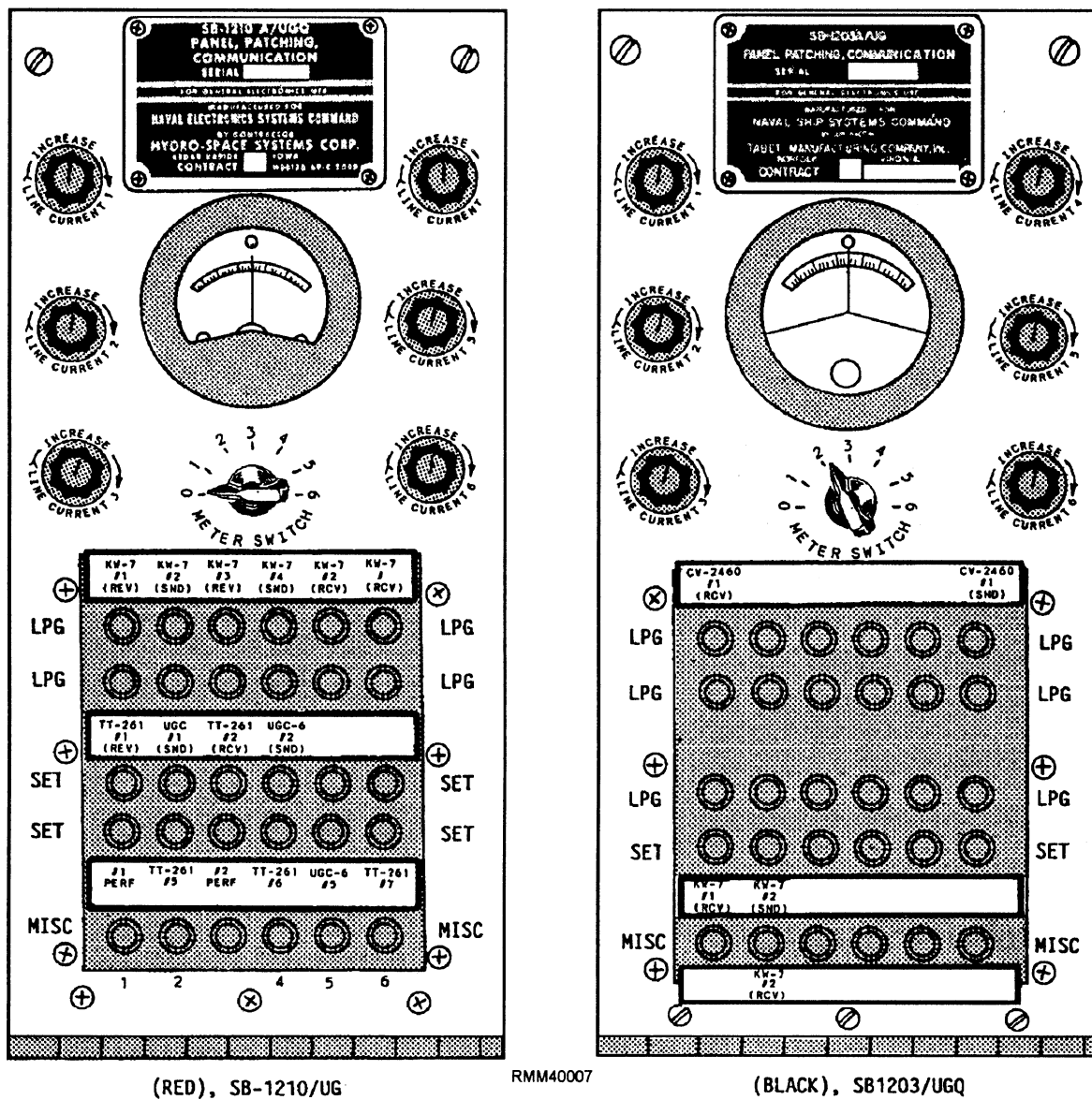


Figure 1-7.—Teleprinter patch panels.

## CRYPTOGRAPHIC EQUIPMENT

Some of the systems in the previous figures contained cryptographic equipment. Cryptographic equipment is only one of a number of the elements that make up a secure communications system. Though several different types of on-line cryptoequipments are in use throughout the naval communications system, they are all designed to perform the same basic function: to encipher and decipher teleprinter or digital data signals.

Simply stated, the transmitter accepts a “plain text” teleprinter or data signal containing classified material from the classified patch panel (red). It then adds a “key,” and relays the sum as “cipher text,” or an enciphered signal. A key is a sequence of random binary bits used to initially set and periodically change permutations in cryptoequipment for decrypting electronic signals.

Following this encryption, the signal is fed to the unclassified patch panel (black). Here, it is patched directly to the frequency-shift keyer or the multiplex equipment of the transmitter and converted into an audio signal. The audio signal, now in a form suitable for transmission, is routed to the transmitter via the transmitter transfer switchboard.

On the receive side, the signal flow is quite similar to the send side in reverse order. The receiver accepts the enciphered signal from the black patch panel and generates a key to match the one generated by the transmitter. The receiver then subtracts the key from the cipher text input (which restores the plaintext teleprinter or data signal). Finally, it passes the signal on to the red patch panel for dissemination to the terminal equipment for printout.

For further information and operator instructions on a specific type of cryptoequipment, refer to the applicable KAO publication.

### AN/UCC-1 TELEGRAPH MULTIPLEX TERMINAL

Because of the traffic volume handled, many ships and shore stations require multiple teleprinter circuits on one sideband circuit. The method for increasing circuits on a sideband is called **multiplexing**. The Navy uses two multiplexing techniques in communications: time division and frequency division. The AN/UCC-1 Telegraph Multiplex Terminal uses the frequency-division technique.

The AN/UCC-1 Telegraph Multiplex Terminal (figure 1-8) is a frequency-division multiplexed terminal equipment for use with single-sideband (SSB) or double-sideband (DSB) radio circuits, audio-frequency wire lines, or microwave circuits. The AN/UCC-1 is normally used afloat on a multichannel ship-shore full-period termination (discussed later).

The following is an overview of how the AN/UCC-1 works:

- At the transmitting station, the signals from the individual circuits, known as *channels*, are multiplexed into one composite signal for transmission. The transmission with the multiplexed channels is known as a *tone package*.
- At the receiving station, the composite signal (tone package) is demultiplexed (separated) into individual signals and distributed to separate teleprinters, as required.

The terminal can operate in a nondiversity, audio-frequency diversity, space diversity, or radio-frequency diversity mode. Because of this versatility, the terminal is installed in various configurations throughout the Navy.

Each electrical equipment cabinet houses one control attenuator (right side) and up to a maximum of eight frequency-shift keyers or eight frequency-shift converters.

Since the control attenuator, keyers, and converters are solid-state, integrated-circuit, plug-in modules, the number of channels can be varied by increasing or decreasing the total number of modules. Depending upon the number of modules and the configuration used, the terminal can provide up to 16 narrowband channels.

For example, if the terminal has keyers in the top cabinet and converters in the bottom cabinet, the system could transmit different information on eight channels. Each keyer would represent a channel on the transmit side and each converter, a channel on the receive side.

Each frequency-shift keyer accepts a dc telegraph signal input from an external loop and generates the appropriate audio-frequency mark and space frequency-shift output. The individual keyers each contain two oscillators operating on opposite sides of a center frequency. For example, in figure 1-9, the center frequency of keyer number one is 425 Hz, the mark frequency is 382.5 Hz, and the space frequency is 467.5

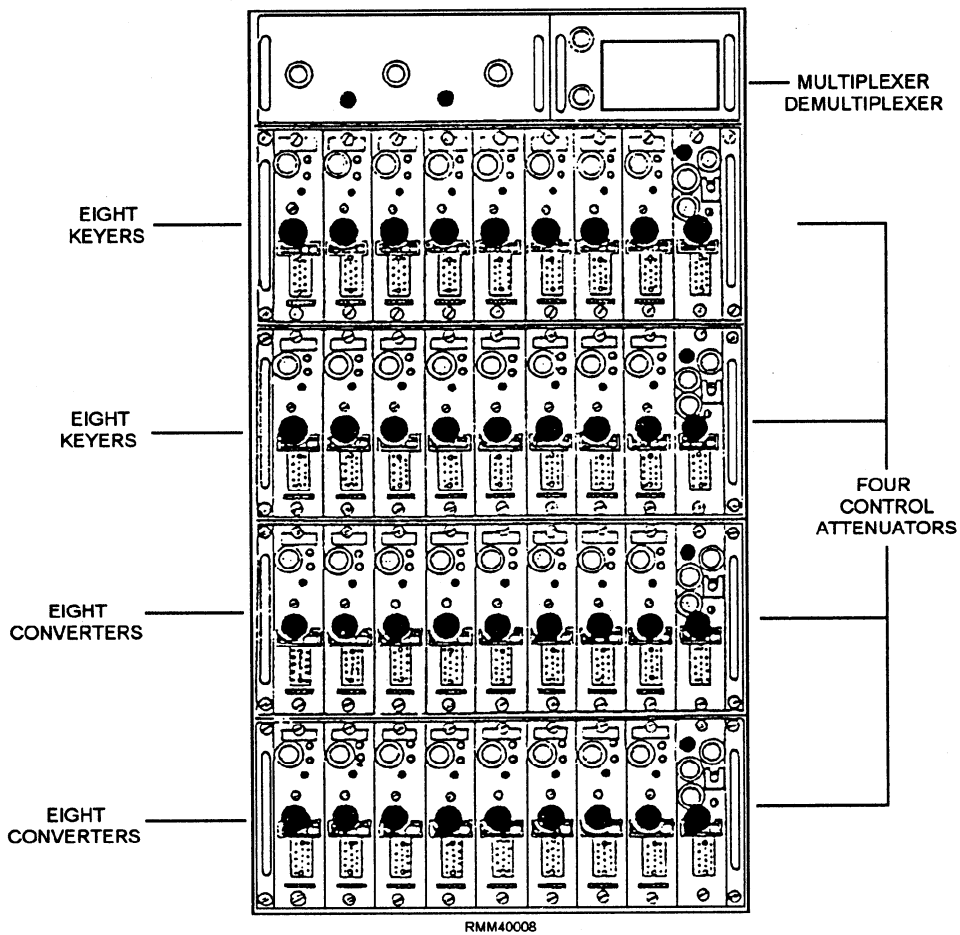


Figure 1-8.—AN/UCC-1 Telegraph Multiplex Terminal.

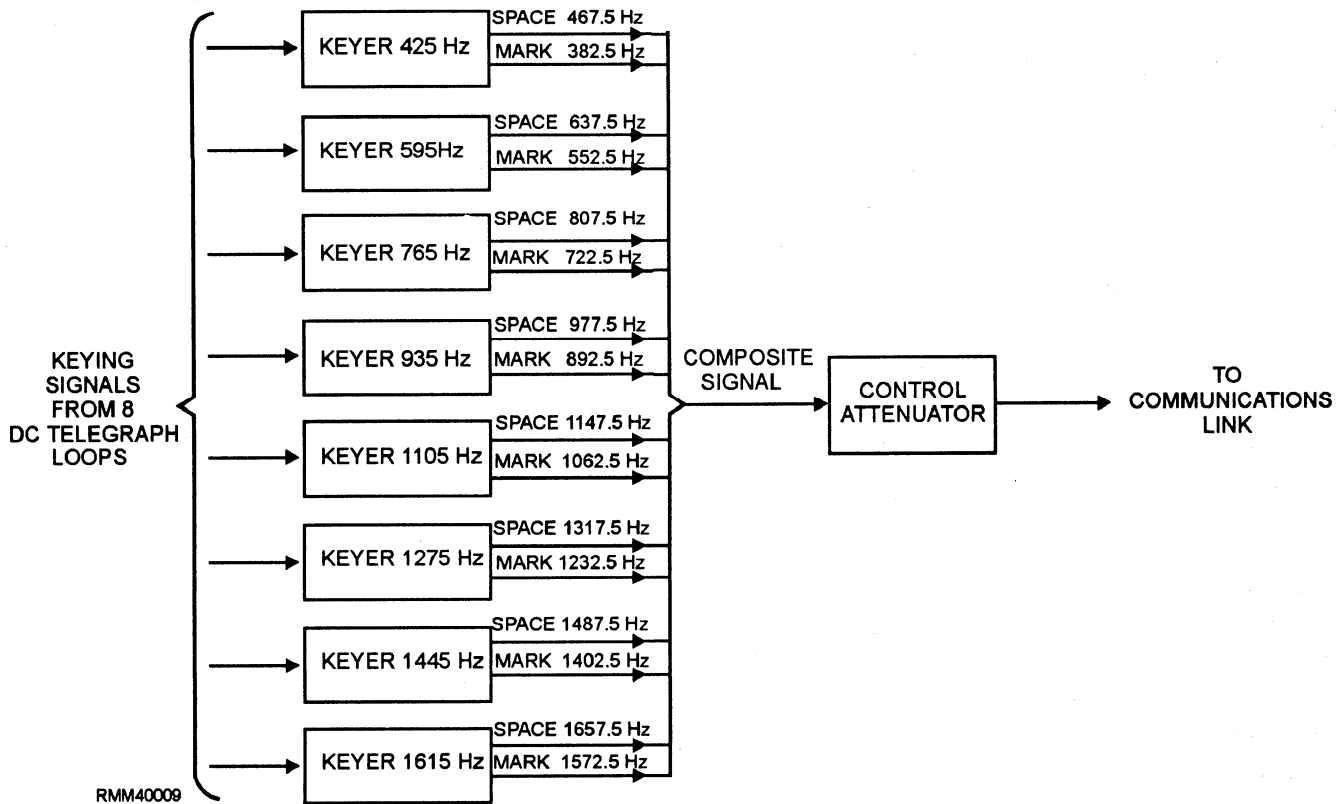


Figure 1-9.—Keying frequencies of the AN/UCC-1.

Hz. These audio-frequency mark and space outputs are referred to as “tones”; thus keyer one has a one-channel, two-tone output.

A dc telegraph signal on channel 1 determines which frequency is gated from the keyer to the group attenuator. Each channel works in the same way. It accepts a dc signal of marks and spaces from selected equipments patched to that channel. It then provides an audio output of either a mark or space frequency-shifted tone, according to the input.

The individual tones are combined at the control attenuator into a composite tone package. The control attenuator ensures that the composite tones remain at a constant amplitude for modulating the transmitter.

At the receiving end of the communications link, the AN/UCC-1 reverses the process performed at the transmitting end. The AN/UCC-1 applies the information on each of the channels to the selected equipments connected to the converter of that channel.

In a frequency-division circuit configuration, each channel has an input from a different teleprinter. If a channel fades at a particular frequency, the information on the channel could be lost or distorted. In such cases, the information may need to be retransmitted. To help prevent this, diversity switches that will permit the use of more than one channel for the same intelligence are available.

In switch position 1, only the normal channel is used. In position 2, a single teleprinter signal provides input for two adjoining keyers. In position 4, four keyers are connected to the same input loop. The switches on all keyers must be in the same position to provide the same intelligence to the selected combination of channels.

When identical intelligence untransmitted on two or four channels, it is less likely to be lost or distorted. At the receiving end, two or four corresponding converters may be used; the converter having the stronger signal

input automatically provides the signal to be used by the receiving teleprinter.

In the fleet broadcast multiplexing system, which consists of 16 channels, 2 channels normally carry the same intelligence. This process is called *twinning*.

Another method of multiplexing mentioned earlier is time-division multiplexing (TDM). In this method, a digital input is fed to a TDM unit. Here, it is multiplexed into a composite intelligence stream for transmission. The output is sent to an end user, where it is broken into its original individual inputs.

However, instead of splitting the frequencies as in frequency-division multiplexing (FDM), TDM shares time. Each input uses the full bandwidth of the assigned frequency but is assigned unique time portions of the system. Figure 1-10 illustrates the front panel of a full-duplex time-diversity modem.

## SHIP-SHORE CIRCUITS

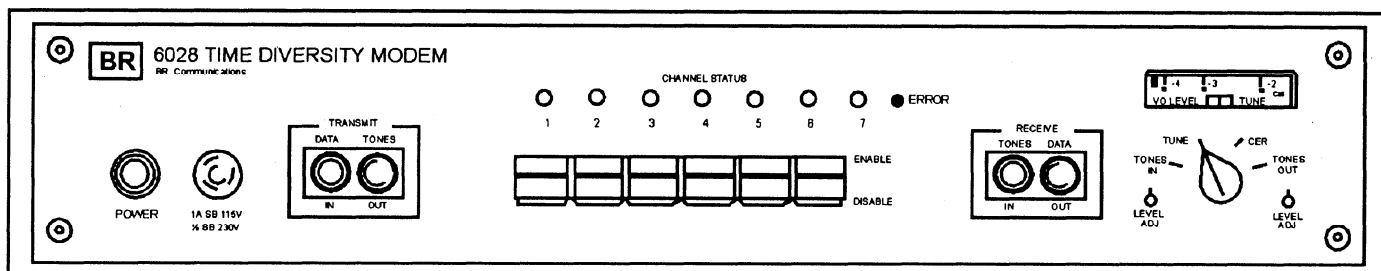
As we mentioned earlier, the fleet broadcast is the primary means for delivering messages to afloat commands. This section discusses a few of the other types of circuits by which a ship can transmit its message traffic ashore or to other ships for delivery or relay.

### SHIP-SHORE CIRCUIT MODES OF OPERATION

There are three methods of operating communications circuits: duplex, simplex, and semiduplex. The mode of operation at any given time depends upon equipment and frequency availability.

#### Duplex

Duplex describes a communications circuit designed to transmit and receive simultaneously. In such operations, each station transmits on a different frequency and both stations transmit concurrently. Both



RMM40010

Figure 1-10.—Full-duplex time-diversity modem.

stations are required to keep transmitters on the air at all times and to send a phasing signal at the request of the distant end. Figure 1-11 shows a diagram of a UHF/HF full-duplex FSK (frequency-shift keying) single-channel teleprinter relay circuit.

There are two types of duplex operation: full duplex and half duplex. Full duplex (FDX) refers to a communications system or equipment capable of transmitting simultaneously in two directions. Half duplex (HDX) pertains to a transmission over a circuit capable of transmitting in either direction, but only one direction at a time.

Small ships traveling in company normally use duplex in a task group common net in which they terminate with a larger ship that is serving as net control. The net control ship provides the ship-shore relay services. Ships traveling independently can use this

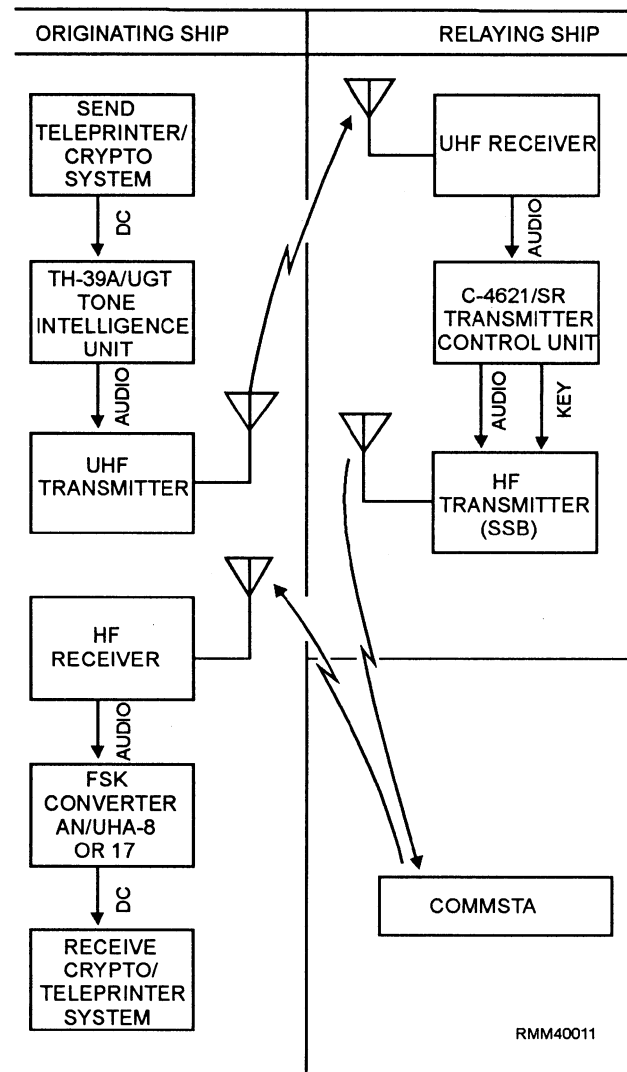


Figure 1-11.—UHF/HF full-duplex FSK single-channel teleprinter relay circuit.

system for anon-call ship-shore termination to transmit their outgoing messages.

### Simplex

Simplex is a method of operation that provides a single channel or frequency on which information can be exchanged (figure 1-12). Simplex communications operation is normally reserved for UHF and those ships that do not have sufficient equipment for duplex operation. In some cases, a simplex circuit can be established when equipment casualties occur.

Where no HF simplex frequency is indicated or guarded, ships requiring a simplex ship-shore circuit must call on a duplex ship send frequency. The ship must state "SIMPLEX" in the call-up, indicating that the ship cannot transmit and receive simultaneously.

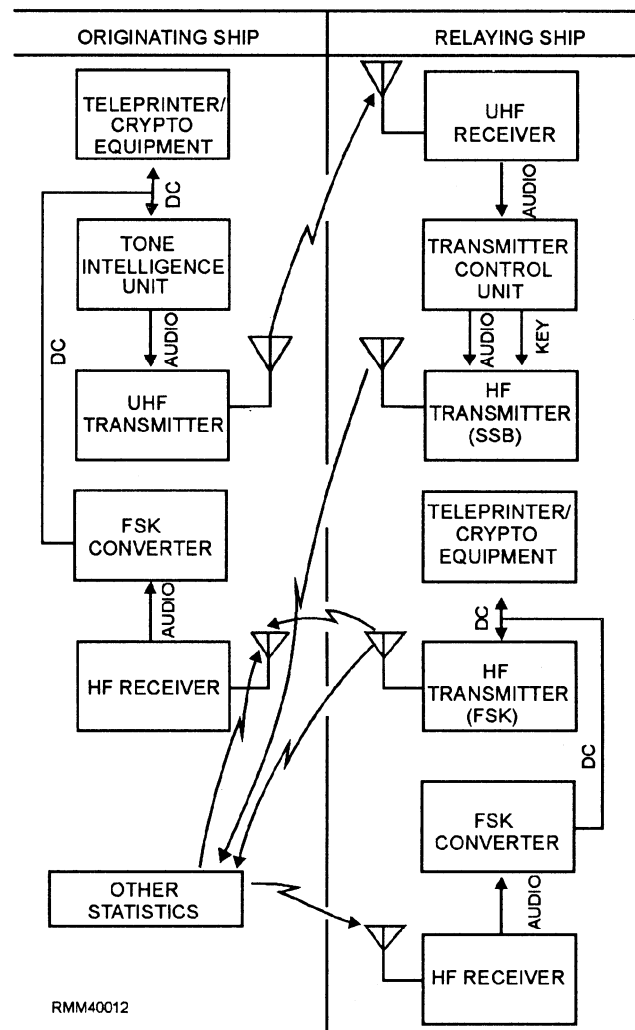


Figure 1-12.—UHF/HF netted simplex FSK teleprinter relay circuit.

When a ship requests simplex operation on duplex circuits, the shore station may be required to shift transmitters prior to acknowledging call-up. If no reply is received within 45 seconds, the ship should repeat the call-up procedures. If a third attempt is required, the ship should check equipment to ensure proper operation.

### Semiduplex

Semiduplex communications circuits, used primarily on task force/task group/ORESTES, are a combination of the simplex and duplex modes. All stations except the net control station (NECOS) transmit and receive on the same frequency. The NECOS transmits and is received on a second frequency. The NECOS may transmit continuously, whereas all other stations must transmit in accordance with simplex procedures.

### UHF/HF RELAY

The UHF/HF relay method permits long-range, uninterrupted communications during periods of hazardous electromagnetic radiation (HERO). Figure 1-13 shows a block diagram of a UHF/HF voice relay circuit.

Modern radio and radar transmitting equipments produce high-intensity RF fields. It is possible for RF energy to enter an ordnance item through a hole or crack in its skin or to be conducted into it by firing leads, wires, and the like. Here is an example of HERO. An aircraft carrier is arming aircraft on board. During arming operations, all HF transmitters must be secured to prevent possible detonation of the ordnance. To maintain its ship-shore communications, the carrier transmits to a relay ship via a UHF circuit. The relaying ship then retransmits the signal on a HF circuit to a terminated NAVCOMTELSTA. On-line

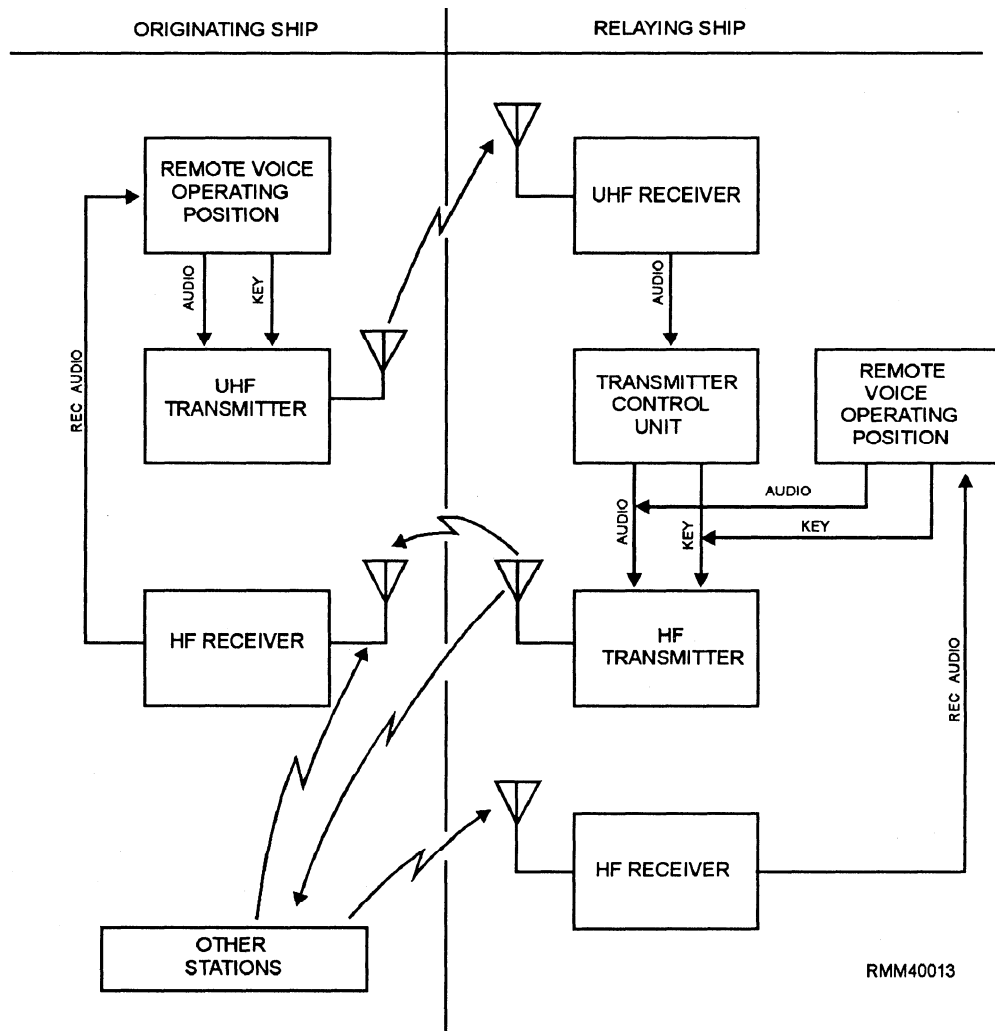


Figure 1-13.—UHF/HF voice relay circuit.

radioteleprinters can be relayed, as well as voice, using this circuit.

## **SECURE VOICE WORLDWIDE VOICE NETWORK**

The secure voice network is designed to provide red-time voice communications between forces afloat and operational commanders ashore, using either HF or satellite connectivity. This system is commonly referred to as GPS Worldwide HICOMM.

### **System Control**

This system consists of three separate networks. Each network has an area control station controlled by a FLTCINC; either CINCLANTFLT, CINCPACFLT, or CINCUSNAVEUR. Each area has subarea control stations determined by each FLTCINC to ensure worldwide coverage.

### **Satellite System Control**

The secure voice system, using satellite transmissions, has limited shore access points at the four COMMAREA master stations and NAVCOMTELSTA Stockton, California. These sites serve as the interface channel to both the wideband and narrowband voice systems in order to extend calls to operational commanders ashore.

### **Net Membership**

If a ship, aircraft, or shore station needs to enter the secure voice network, it must be prepared to do so with minimum time delay. Units desiring to enter the net on a temporary basis must specify the length of time and purpose for entering the net. They must also obtain permission from the appropriate control station. The area net control station (NECOS) is responsible for completing all calls originating from senior commands to all commands, ships, or aircraft within the specific FLTCINC's net. Certain rules must be observed when on the secure voice net, as follows:

- HF transmitter tuning is prohibited on secure voice. Transmitters must be calibrated and pretuned on a dummy load. Final tuning may be accomplished during live transmissions.
- All stations must maintain a continuous log on secure voice. The actual time of significant transmissions must be entered into the log. When available, recording devices must be used in lieu of a paper log.

- The net operates as a free net unless otherwise directed by the area FLTCINC. NECOS retains the prerogative of exercising control over all transmissions to ensure proper circuit discipline.

## **FULL-PERIOD TERMINATIONS**

Full-period terminations are dedicated circuits that provide communications between shore stations and afloat commands. These terminations require allocation of limited NCTAMS/NCTS assets. Therefore, the criteria for requesting, approving, and establishing such circuits is necessarily strict.

### **Termination Requests**

Afloat commands and individual units can request full-period termination during special operations, deployments, intensive training periods, or exercises when primary ship-shore circuits will not suffice. Commands should request full-period terminations only when traffic volume exceeds speed and capability of ship-shore circuits and when operational sensitivity requires circuit discreetness or effective command and control necessitates dedicated circuits.

The heavy demands placed upon NCTAMS/NCTSs for full-period terminations require maximum cooperation between shore stations and afloat commanders prior to and during an operation. Ships having a need for a full-period termination, either for training or operational requirements, must submit a termination request to the COMMAREA master station at least 48 hours prior to activation time.

Emergency commitments or a command directive may necessitate a lead time of less than 48 hours. Whenever possible, however, the 2-day limit must be honored to achieve maximum preparation and coordination. NTP 4 gives details of required information that must be included in a termination request message.

The COMMAREA master station will assign a shore station for a ship's termination circuit. Once the shore station has been assigned, both the ship and the station may begin coordination to identify specific equipment keylists and frequencies needed to effect termination. The shore station will also act as NECOS. Two hours prior to the scheduled termination, the shore station can coordinate with the ship by telephone, local circuitry, or by primary ship-shore.

When the ship shifts terminations, the securing of the current termination and the establishment of a new

termination should coincide with a broadcast shift whenever possible. The ship must submit a COMMSHIFT message.

### **Termination Types**

There are six types of full-period terminations, as follows:

- Single-channel radioteleprinter using either radio path or landline transmission media;
- Single-channel low-data-rate satellite access using satellite transmission media;
- CUDIXS special satellite access for NAVMACS-equipped ships using satellite transmission media;
- Multichannel radioteleprinter using either radio path or landline transmission media;
- Multichannel radioteleprinter using SHF satellite transmission media; and
- Tactical intelligence (TACINTEL) access for TACINTEL-equipped ships using satellite transmission media.

### **Equipment Tests**

To ensure that circuit equipment is in peak operational condition, complete system back-to-back off-the-air tests must be completed 24 hours prior to termination activations. Check cryptoequipment back-to-back after daily crypto changes and prior to putting circuits into service.

An aggressive PMS and quality monitoring program is essential. When checking equipment, look for power levels, scorch or burn marks, proper operation of interlocks, and cleanliness. When cleaning and inspecting antennas, look for cracks, chips, or blistering of insulators. Also check for deterioration, loose connectors, and correct insulator resistance.

### **COMMSPOT Reports**

COMMSPOT reports will be submitted by all ships, including nonterminated units, any time unusual communication difficulties are encountered. Ships will submit the COMMSPOT to the terminating communications station. Timely submission of COMMSPOT reports is necessary to minimize further deterioration of the situation.

Rules and general instructions for preparing JINTACCS formatted COMMSPOT reports are found in the *Joint Reporting System (General Purpose Reports)*, NWP 1-03, Supp-1 (formerly NWP 10-1-13).

### **PRIMARY SHIP-SHORE CIRCUITS**

Primary ship-shore (PRI S/S) circuits are encrypted FSK/PSK teleprinter nets that permit ships to transmit messages for delivery ashore. This service is available to units that do not maintain a full-period ship-shore termination. Navy tactical UHF satellites or the HF/UHF spectrum may be used to conduct ship-shore circuit operations. Ships may use this circuit for coordinating and establishing a full-period termination with the shore station.

The frequencies for NCTAMS and NAVCOMTELSTAS that guard primary fleet ship-shore circuits are listed in applicable CIBs distributed by the COMMAREA master stations. These frequencies are subject to change by the cognizant FLTCINC or by the NCTAMS.

### **OVER-THE-AIR TRANSFER (OTAT) AND OVER-THE-AIR REKEY (OTAR)**

There are significant vulnerabilities associated with the handling of paper cryptographic material. Sound application of over-the-air transfer/rekey (OTAT/OTAR) procedures and techniques can reduce the amount of paper keying material required and reduce the potential for compromise. These procedures and techniques are contained in the *NAG-16B Procedures Manual for Over-the-Air Transfer (OTAT) and Over-the-Air Rekey (OTAR)*.

OTAT/OTAR also makes the transfer of keying material more responsive to rapidly changing operational requirements. The use of NAG-16B was developed and verified by extensive use during operation Desert Shield/Storm. The specified procedures served as an effective vehicle for transferring keying to satisfy rapidly changing joint and Navy requirements. Expanded definitions, general procedures, and equipments are found in NAG-16B.

### **DISTRESS COMMUNICATIONS**

Special methods of communication have been developed to use in times of distress and to promote safety at sea and in the air. Distress message traffic is best described as all communications relating to the immediate assistance required by a mobile station in



distress. Distress traffic has priority over all other traffic. All U.S. Navy communicators must be familiar with distress signals to properly evaluate their meanings and to take appropriate action when necessary.

If a ship becomes involved in a distress situation, communications personnel should send distress messages on normal operating encrypted circuits. If the need for assistance outweighs security considerations, the ship's commanding officer may authorize the transmission of an unclassified distress message on one of the national or international distress frequencies.

When a ship in distress is traveling in company with other ships, the ship in distress will transmit the distress message to the officer in tactical command (OTC), who will take appropriate action.

## **DISTRESS FREQUENCIES**

Several frequencies in different bands are designated for the transmission of distress, urgency, safety, or search and rescue (SAR) messages. The following frequencies have been designated for use during a distress or emergency situation:

- **500 kHz**— International CW/MCW distress and calling;
- **2182 kHz**— International voice distress, safety, and calling;
- **8364 kHz**— International CW/MCW lifeboat, life raft, and survival craft;
- **121.5 MHz**— International voice aeronautical emergency;
- **156.8 MHz**— FM United States voice distress and international voice safety and calling; and
- **243.0 MHz**— Joint/combined military voice aeronautical emergency and international survival craft.

During SAR missions, the following frequencies are authorized for use:

- **3023.5 and 5680 kHz**— International SAR frequencies for the use of all mobile units at the scene of a search. Also for use of shore stations communicating with aircraft proceeding to or from the scene of the search. CW and voice are authorized.
- **123.1 MHz**— International worldwide voice SAR use.

- **138.78 MHz**— U.S. military voice SAR on-the-scene use. This frequency is also used for direction finding (DF).
- **172.5 MHz**— U.S. Navy emergency sonobouy communications and homing use. This frequency is monitored by all U.S. Navy ASW aircraft assigned to a SAR mission.
- **282.8 MHz**— Joint/combined on-the-scene voice and DF frequency used throughout NATO.

The control of distress message traffic on any designated frequency is the responsibility of the station in distress. However, this station may delegate its responsibility to another station on the frequency.

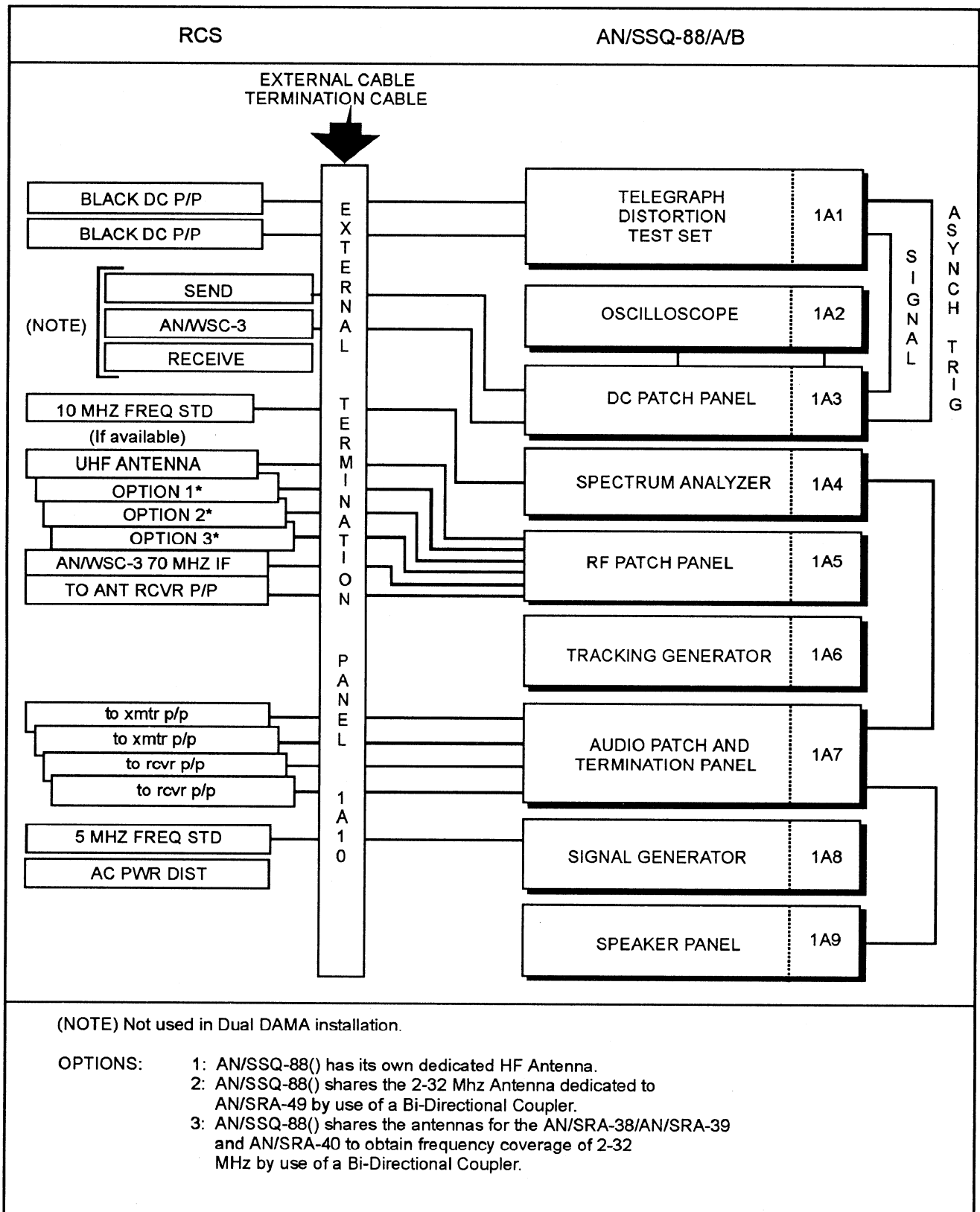
## **Distress Watches**

Navy units at sea have always maintained listening watches on distress frequencies. Communication watch requirements vary according to the operational mission of the ship and available equipment assets. Ships in company normally divide distress watch requirements among the group.

## **STATUS BOARD**

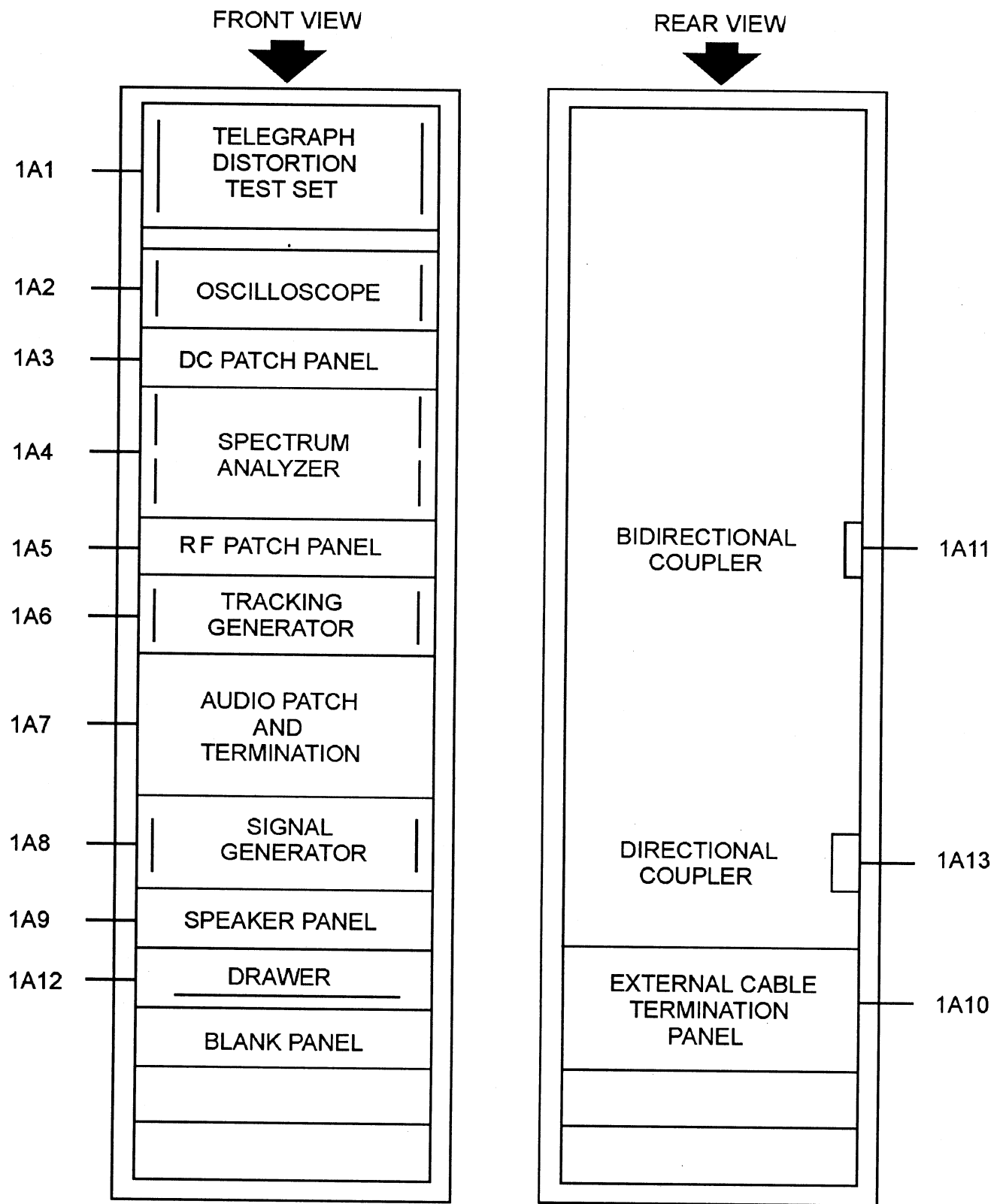
The technical control of the shore station that is NECOS for fill-period terminations and PRI S/S circuits must maintain a status board. The status board should indicate, as a minimum, all systems/circuits that are active, tuned in, or in a standby status. It should also indicate all inoperative equipment. The watch supervisors must verify the accuracy of the information contained on the status board at watch turnover and update while on watch. The status board must show the following minimum information for active and standby circuits:

- Functional title of circuit;
- Frequency(ies), both send/receive, if fill-duplex operation is used;
- Circuit designator, from communication plan;
- Transmitter and receiver designations;
- For shore stations, keying line designations;
- Terminal equipment designation (for example, R-2368/URR #1);
- Cryptoequipment, keying material, and restart time;



RMM40014

Figure 1-14.—AN/SSQ-88 Quality Monitoring Set and RCS interface.



RMM40015

Figure 1-15.—AN/SSQ-88 equipment configuration.

- Operating position or remote control unit designation; and
- Remarks, as appropriate.

## QUALITY MONITORING

In recent years, the volume of communications has increased dramatically. This rapid expansion has led to the installation of increasingly sophisticated equipment. Such factors as frequency accuracy, dc distortion, inter-modulation distortion (IMD), and distribution levels are critical to the operation of communications systems.

Satisfactory operation of these systems demands precise initial line-up and subsequent monitoring. System degradation is often caused by many small contributing factors that, when combined, render the system unusable. Simply looking at the page printer or listening to the signal is inadequate.

Simply stated, quality monitoring is the performance of scheduled, logical checks that will ensure continuous, optimum performance and, in many cases, prevent outages before they occur. Some communications personnel quite often fail to realize the benefits of quality monitoring. An attitude develops that questions the need for quality monitoring. The result of this incorrect attitude is that circuits are either **UP** or **DOWN**. Personnel with this attitude perform no quality monitoring when the circuits are **UP** and are, therefore, forced to treat each outage as if it were a unique occurrence.

With no precise information concerning the trend of the system's performance, personnel must jump from one assumed probable cause to another assumed probable cause, while valuable circuit time is lost. A ship with an aggressive quality monitoring program usually has personnel who are thoroughly familiar with all installed communications systems.

## QUALITY MONITORING PROGRAM

The primary function of the quality monitoring program is the direct measurement of signal quality characteristics, including:

- Dc distortion;
- Audio distribution level;
- Frequency accuracy of RF signals;
- Spectrum analysis; and

- Loop current.

These measurements are broad categories and can be broken down to specific tests for specific systems.

## Quality Monitoring System

Figure 1-14 is a diagram of a quality monitoring system and RCS interface. The system was designed to provide a means of monitoring and evaluating performance of any communications system used by forces afloat.

The monitoring system is a grouping of specific test equipments into a console designated as the AN/SSQ-88 Quality Monitoring Set. The set contains equipment for measuring and analyzing signals sampled by sensors installed in each communications circuit interface. The system should be operated only by personnel with sufficient knowledge to analyze the signals being transmitted and received via the ship's circuits, including individual channels of the multichannel circuits.

The console configuration shown in figure 1-15 may not be compatible with all ships; however, most ships can use equivalent test equipment to establish a quality monitoring test system.

## SUMMARY

Your commanding officer must be able to communicate with ships and shore stations to maintain effective command and control of the situation at hand. Communications are, and always will be, the "voice of command." In the age of nuclear weapons, guided missiles, supersonic aircraft, and high-speed ships and submarines, top performance is required of our fleet communicators. You, as a Radioman, and your equipment must always be in constant readiness to meet this formidable challenge.

Distress communications are methods that have been developed for use in times of distress. They indicate the need for immediate assistance and have priority over all other traffic. Various publications and local instructions will assist you in carrying out your required responses to these situations.

Communication systems are periodically tested to ensure that they operate efficiently and accurately. The combined tests, checks, and measurements help determine the condition of systems, subsystems, and individual equipments. Tests and measurements of communication systems and equipments range from the very simple to the very complex.

## CHAPTER 2

# SATELLITES AND ANTENNAS

### LEARNING OBJECTIVES

*Upon completing this chapter, you should be able to do the following:*

- *Identify the theory relating to satellites.*
  - *Calculate azimuth and elevation, using plotting guides.*
  - *Identify the types, basic system and fleet broadcast subsystem equipment of communication satellites.*
  - *Identify the characteristics of antennas and antenna selections.*
  - *Identify the types of antennas.*
  - *Explain how the distribution systems interface with antenna assignment and selections.*
  - *Identify the procedures for setting up antenna couplers, multicouplers, transmitters, and transceivers.*
  - *Explain how the patch panel is used in conjunction with the equipment.*
  - *Identify the procedures for raising and lowering antennas.*
  - *Determine the optimum reception of a directional antenna by rotation, alignment, and tuning.*
  - *Identify safety precautions that should be observed when working on antennas.*
- 

Satellite communication (SATCOM) systems satisfy many military communications requirements with reliable, high-capacity, secure, and cost-effective telecommunications. Satellites provide a solution to the problem of communicating with highly mobile forces deployed worldwide. Satellites also provide an alternative to large, fixed ground installations. They provide almost instantaneous military communications throughout the world at all but the highest latitudes (above 700).

### SATCOMM ANTENNAS

The antennas shown in figures 2-1 and 2-2 are used for satellite communications. The OE-82C/WSC-1(V) antenna (figure 2-1) is used with the AN/WSC-3 transceiver and designed primarily for shipboard installation. Depending upon requirements, one or two antennas may be installed to provide a view of the satellites at all times. The antenna is attached to a pedestal. This permits the antenna to rotate so that it is always in view of the satellite. The frequency band for receiving is 248 to 272 MHz; the band for transmitting is 292 to 312 MHz.

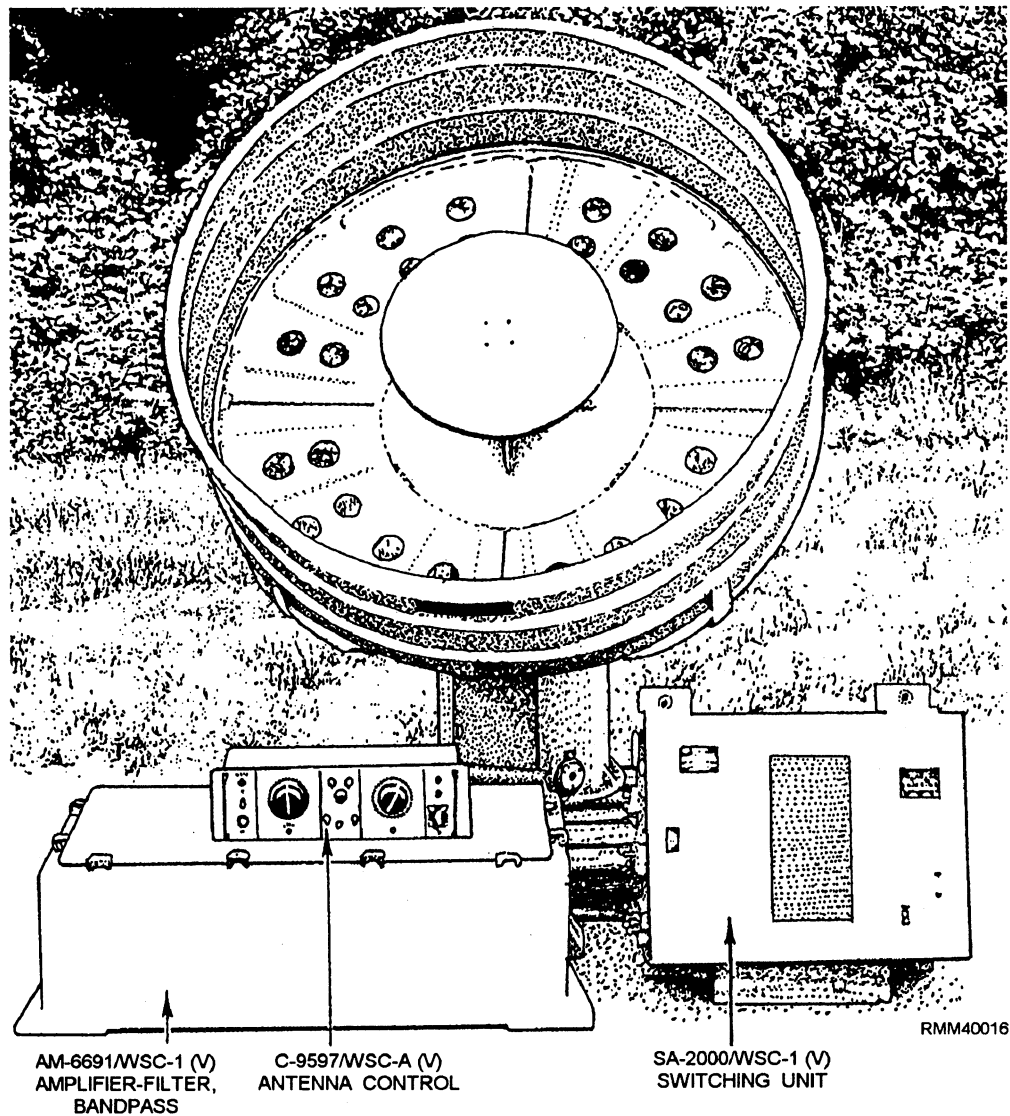


Figure 2-1.—OE-82C/WSC-1(V) antenna group.

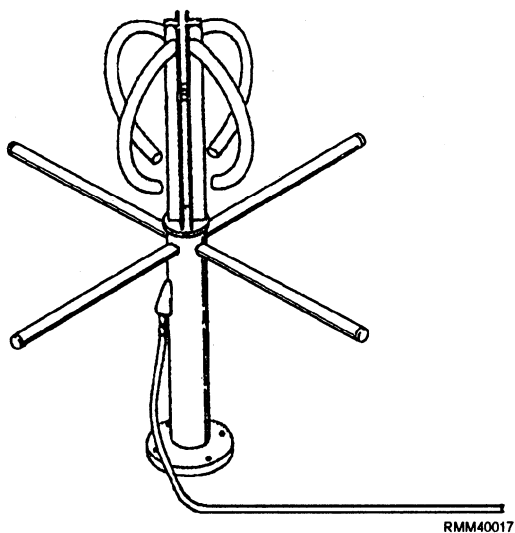


Figure 2-2.—AS-2815/SSR-1 antenna physical configuration.

The AN/SRR-1 receiver system consists of up to four AS-2815/SSR-1 antennas (figure 2-2) with an amplifier-converter, AM-6534/SSR-1, for each antenna. The antennas are used to receive satellite fleet broadcasts at frequencies of 240 to 315 MHz. The antenna and converters are mounted above deck so that at least one antenna is always in view of the satellite.

The newer satellite systems use the SHF band. One of the major advantages of these systems is that they use a very small parabolic antenna measuring only 12 inches in diameter.

A satellite antenna must be pointed at the satellite to communicate. We must first determine the azimuth (AZ) and elevation (EL) angles from a fixed location. Figure 2-3 illustrates how these angles are derived,

using a pointing guide called the Equatorial Satellite Antenna Pointing Guide. This guide is normally available through the Navy Supply System.

The antenna pointing guide is a clear plastic overlay, which slides across a stationary map. It indicates AZ and EL angles in degrees to the satellite. The values obtained are useful to the operator in setting up the antenna control unit of a satellite system.

To use the guide, follow these procedures:

- Center the overlay directly over the desired satellite position on the stationary map.
- Mark the latitude and longitude of the ship on the plastic antenna pointing guide with a grease pencil.
- Determine the approximate azimuth angle from the ship to the satellite.
- Locate the closest dotted line radiating outward from the center of the graph on the overlay in relation to the grease dot representing the ship's

location. This dotted line represents degrees of azimuth as printed on the end of the line. Some approximation will be required for ship positions not falling on the dotted line.

- Determine the degrees of elevation by locating the solid concentric line closest to the ship's marked position. Again, approximation will be required for positions not falling directly on the solid elevation line. Degrees of elevation are marked on each concentric line.

**Example:** Assume that your ship is located at 30° north and 70° west. You want to access FLTSAT 8 at 23° west. When we apply the procedures discussed above, we can see the example indicates an azimuth value of 115° and an elevation angle of 30°.

### TYPES OF SATELLITES

Three types of communications satellites are in use by the U.S. Navy today. They are GAPFILLER, Fleet Satellite Communication (FLTSATCOM), and Leased

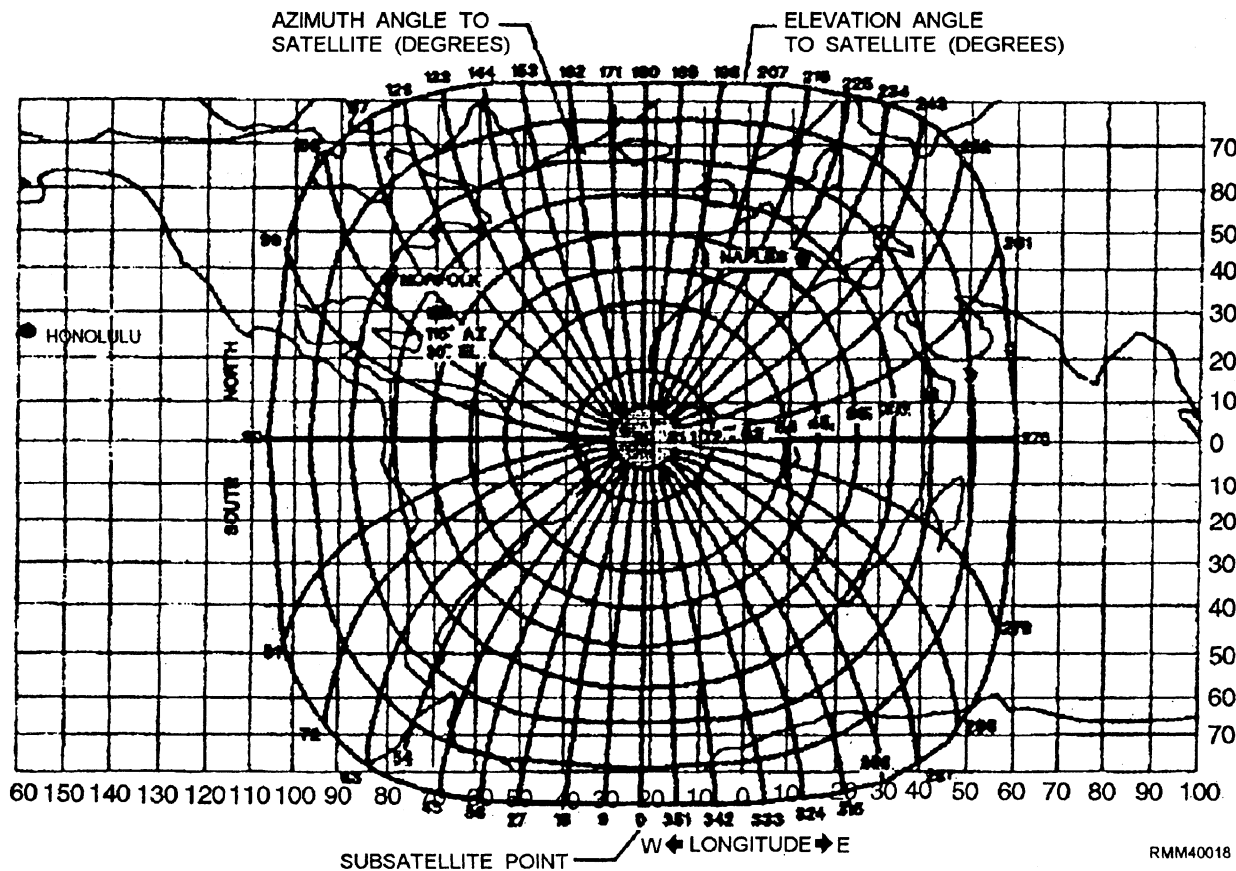


Figure 2-3.—Equatorial Satellite Antenna Pointing Guide.

Satellite (LEASAT) (figure 2-4). These satellites are in geosynchronous orbit over the continental United States and the Atlantic, Pacific, and Indian oceans. Each satellite is described in the following paragraphs.

### GAPFILLER

In 1976, three satellites, called MARISAT, were placed into orbit over the Atlantic, Pacific, and Indian oceans. Each satellite had three UHF channels for military use, one wideband 500-kHz channel, and two narrowband 25-kHz channels.

The Navy leased the UHF section of each satellite for communications purposes. To distinguish the special management and control functions for

communications on these UHF channels, the Navy gave the name GAPFILLER to the leased satellite assets.

GAPFILLER was intended to fill the need for a continuing satellite communications capability in support of naval tactical operations until the Navy achieved a fully operable Fleet Satellite Communications (FLTSATCOM) system.

The GAPFILLER satellite over the Indian Ocean is the only one still being used by the U.S. Navy. The other two GAPFILLER satellites were replaced by LEASAT. The active GAPFILLER satellite will also be replaced by LEASAT as it reaches the end of its operational life.

Within the 500-kHz band, transponders provide 20 individual 25-kHz low- and high-data-rate communications channels for 75 baud ship-shore

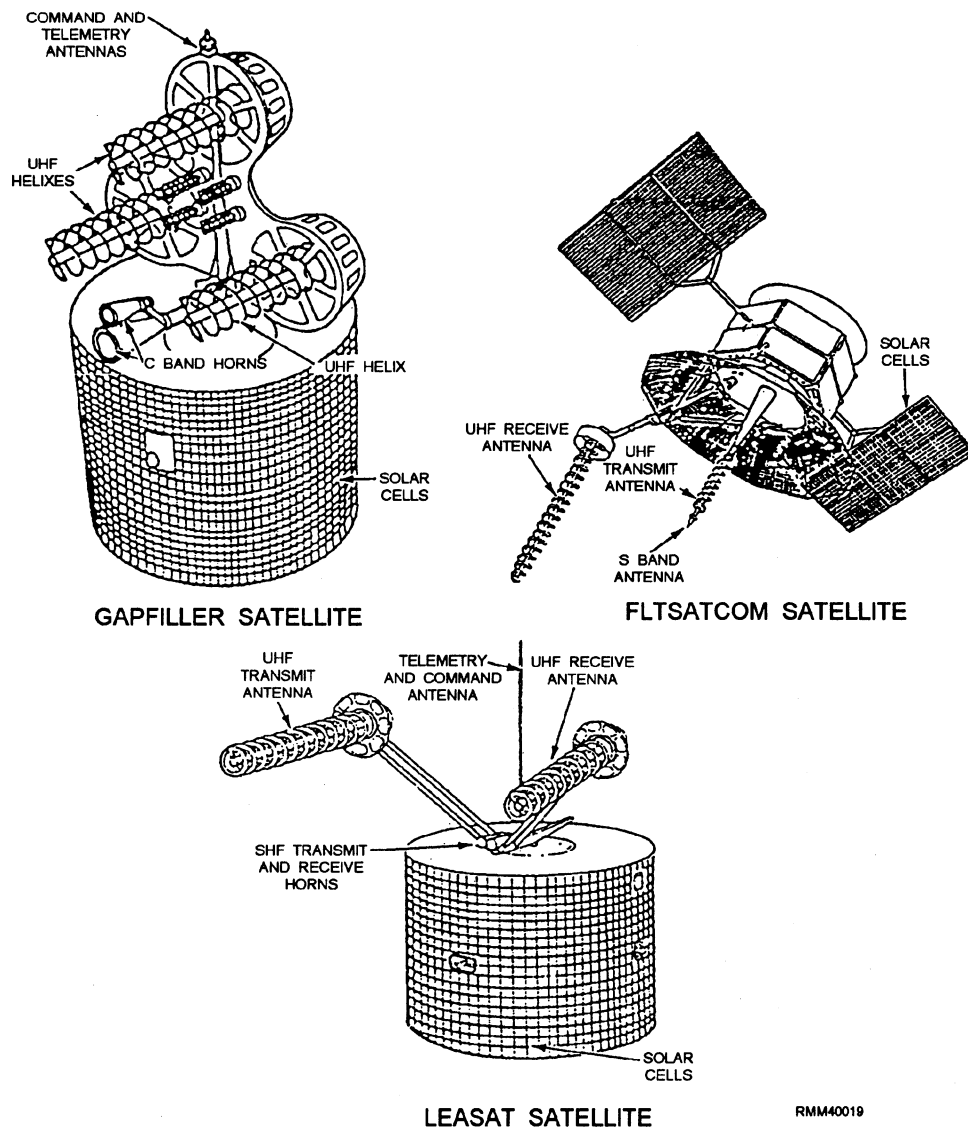


Figure 2-4.—GAPFILLER, FLTSATCOM, and LEASAT satellites.



communications and for the automated information exchange systems. The UHF receiver separates the receive band (302 to 312 MHz) from the transmit band (248 to 258 MHz).

The receiver translates the received carriers to intermediate frequencies (IFs) in the 20-MHz range and separates them into one of three channels. One channel has a 500-kHz bandwidth, and two have a bandwidth of 25 kHz each. The signals are filtered, hard limited, amplified to an intermediate level, and up-converted to the transmit frequency. Each channel is then amplified by one of three high-power transmitters.

GAPFILLER also supports the FLTSATCOM system secure voice system and the fleet broadcast in the UHF range. The GAPFILLER communications subsystem will eventually be replaced by the FLTSATCOM system.

### FLTSATCOM

There are four FLTSATCOM satellites in service. These satellites are positioned at 100° W, 72.5° E, 23° W, and 172° E longitudes. They serve the Third, Sixth, Second, and Seventh fleets and the Indian Ocean battle groups. These four satellites provide worldwide

coverage between 70° N and 70° S latitudes (figure 2-5).

Each FLTSATCOM satellite has a 23-RF-channel capability. These include 10 25-kHz channels, 12 5-kHz channels, and 1 500-kHz channel. The 500-kHz and the 10 25-kHz channels are reserved for Navy use. Of the 10 25-kHz channels, channel 1 is used for the fleet broadcast. All channels use SHF for the uplink transmission. SHF is translated to UHF for the downlink transmission.

There is a separate UHF downlink transmitter for each channel. Each of the 23 channels has 3 different frequency plans in which the uplink or downlink may be transmitted. This capability precludes interference where satellite coverage overlaps.

### LEASAT

The latest generation of Navy communications satellites is leased; hence, the program name LEASAT. As we mentioned earlier, these satellites replaced 2 of the 3 GAPFILLER satellites and augment the FLTSATCOM satellites.

CONUS LEASAT (L-3) is positioned at 105° W longitude, LANT LEASAT (L-1) is positioned at

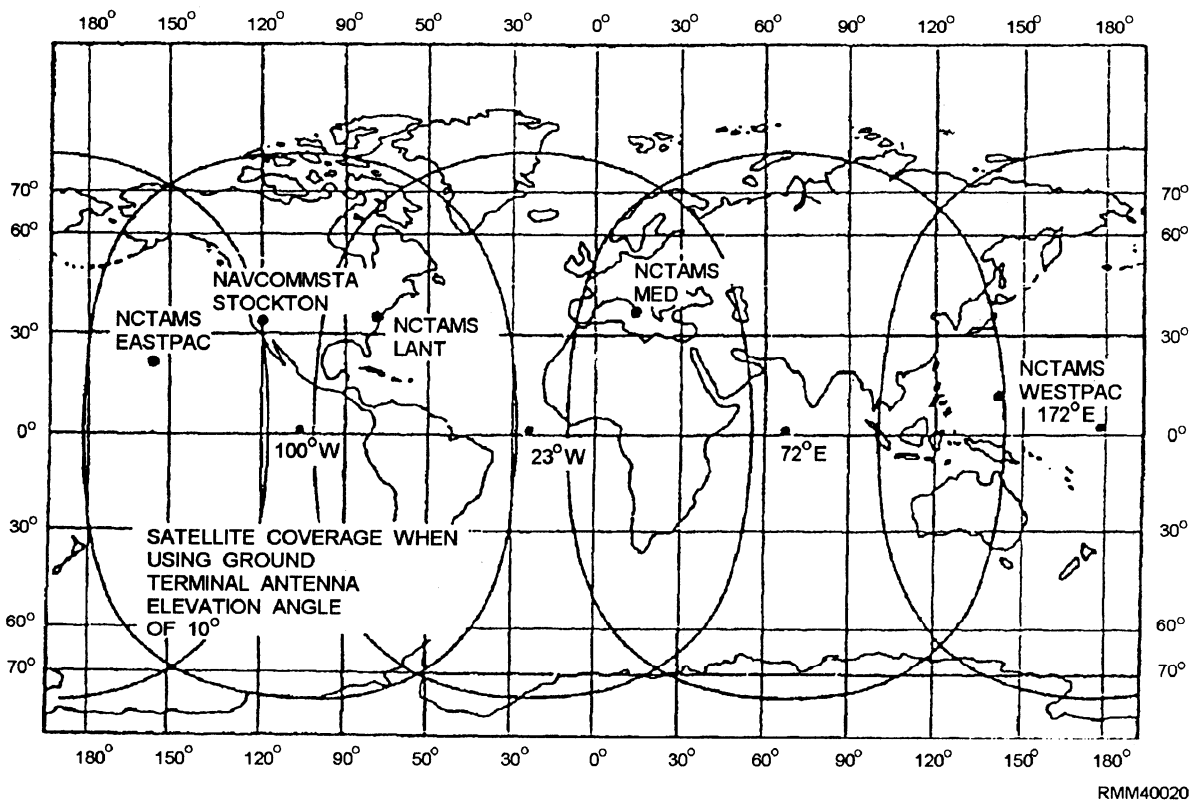


Figure 2-5.—FLTSATCOM coverage areas,

15° W longitude, and 10 LEASAT (L-2) is positioned at 72.5° E longitude (figure 2-6).

Each LEASAT provides 13 communications channels using 9 transmitters. There are 7 25-kHz UHF downlink channels, 1 500-kHz wideband channel, and 5 5-kHz channels. The 500-kHz channel and the 725-kHz channels are leased by the Navy. One of the 725-kHz UHF downlink channels is the downlink for the Fleet Satellite Broadcast.

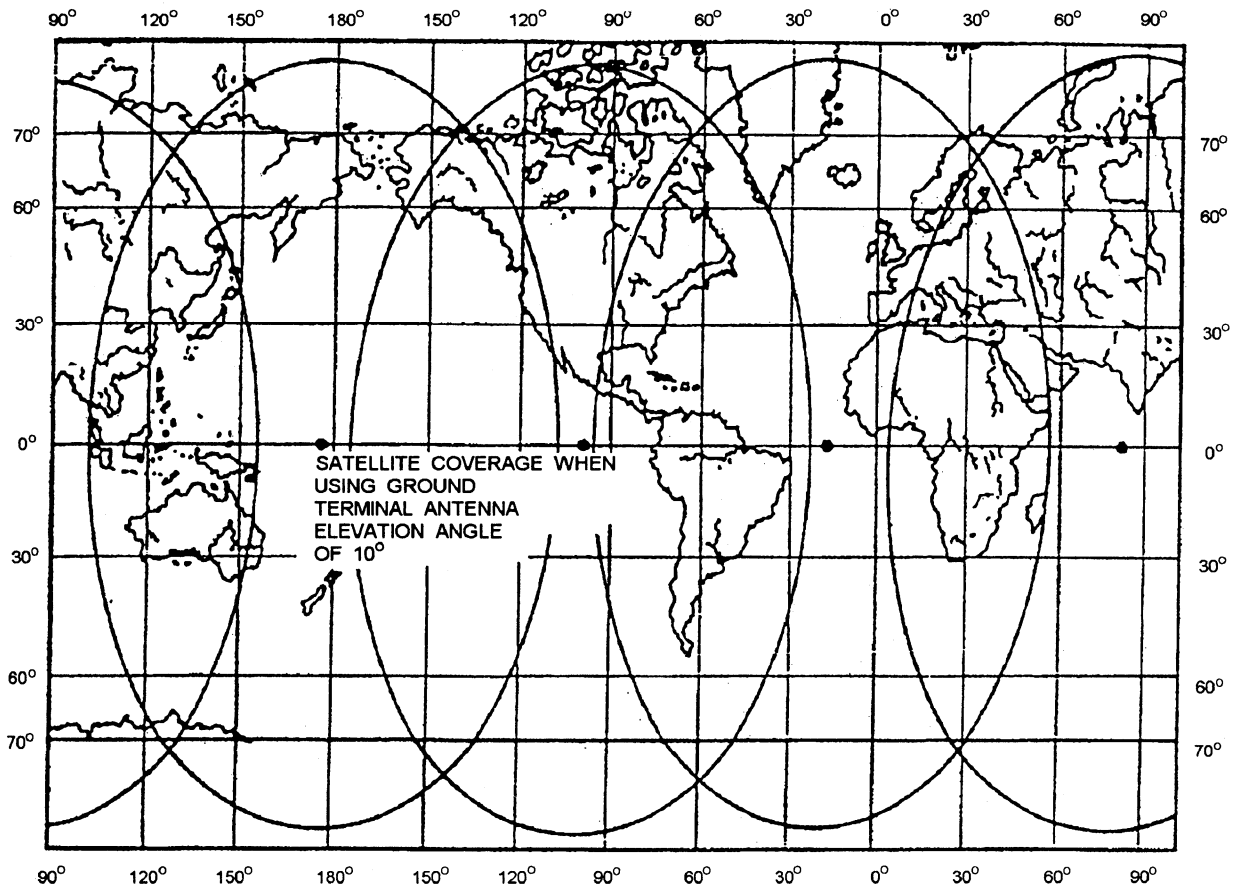
The broadcast uplink is SHF, with translation to UHF taking place in the satellite. The remaining 625-kHz channels function as direct-relay channels with several repeaters. Currently, the LEASAT channels provide for the following subsystems:

- Channel 1 for Fleet Satellite Broadcast transmissions;
- 1 25-kHz channel for SSIXS communications;
- 1 25-kHz channel for ASWIXS communications; and

- 2 25-kHz channels for subsystems that transmit or receive via DAMA (Demand Assigned Multiple Access) (for example, CUDIXS/NAVMACS, TACINTEL, and secure voice).

#### PHASE IV

Operations Desert Shield/Desert Storm reinforced the requirement for and greatly accelerated the introduction of SHF SATCOM capability on aircraft carriers and amphibious flagships to satisfy minimum tactical command and control (C2), intelligence and warfighting communications requirements while improving Joint and NATO/Allied communications interoperability. To meet the urgent operational requirement, the U.S. Navy obtained and modified U.S. Air Force AN/TSC-93B Ground Mobile Forces (GMF) SHF SATCOM vans for installation on aircraft carriers and amphibious flagships deploying to the Persian Gulf. The modified vans were coupled with the AN/WSC-6(V) standard U.S. Navy SHF stabilized antenna system, the SURTASS modem, 2 low speed time division multiplexer (LSTDMs), and additional



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Figure 2-6.—LEASAT coverage areas.

patch panels. The modified SATCOM terminals were designated "QUICKSAT". The initial introduction of these terminals into the fleet officially marked the beginning of Phase I of the U.S. Navy's SHF SATCOM fielding plan (with everything prior being referred to as Phase 0) and provided an immediate operational capability.

Phase II of the U.S. Navy's SHF fielding plan, which commenced in FY 94, will replace QUICKSAT terminals on aircraft carriers with an AN/WSC-6(V)4 terminal. The U.S. Navy will also deploy an SHF Demand Assigned Multiple Access (DAMA) modem. This phase replaces the QUICKSAT terminals on aircraft carriers, and adds SHF SATCOM capabilities to more ships.

Commencing in FY97, Phase III will deploy the next AN/WSC-6 variant. The new terminal will be a modem, modular, open architecture terminal capable of providing a full spectrum of SHF SATCOM services and greatly expand the number of installations.

The system configuration that supports Navy SHF SATCOM consists of an SHF RF terminal and supporting baseband equipment. The RF terminals for shipboard use are the AN/WSC-6(V) or AN/TSC-93B (MOD) "QUICKSAT" terminal. The terminals process and convert the RF signal transmitted to or received from the space segment. The transmit frequency range is 7.9 to 8.4 GHz, and the receive range is 7.25 to 7.75 GHz. The OM-55(V)/USC AJ modems, 1105A/1106 time division multiple access (TDMA)/DAMA modem, and the CQM-248A (phase shift keying (PSK) modems) are deployed on shipboard platforms.

The AN/WSC-6(V) and QUICKSAT configured terminals are compatible with present and future DSCS SHF satellite ground terminals and consist of an antenna group, radio set group and modem group. The antenna group is configured as either a dual or single antenna system. The AN/WSC-6(V)1, with the MD-1030A(V) modem, is used on SURTASS ships equipped with a single antenna. The AN/WSC-6(V)2, with the OM-55(V)/USC, Frequency Division Multiple Access (FDMA) or TDMA/DAMA modems, is used on both flag and flag-capable platforms and is configured with either a single or dual antenna. The QUICKSAT terminal is configured with an FDMA modem, single or dual antenna, and deployed on selected aircraft carriers and amphibious flagships. The AN/WSC-6(V) and QUICKSAT terminals automatically track the selected satellite, while simultaneously transmitting and receiving. An antenna control unit commands the antenna to search for tracking (beacon) signals from the

satellite. Upon satellite acquisition, tracking is accomplished automatically.

## BASIC SATCOM SYSTEM

A satellite communications system relays radio transmissions between Earth terminals. There are two types of communications satellites: active and passive. An active satellite acts as a repeater. It amplifies signals received and then retransmits them back to Earth. This increases the signal strength at the receiving terminal compared to that available from a passive satellite. A passive satellite, on the other hand, merely reflects radio signals back to Earth.

A typical operational link involves an active satellite and two Earth terminals. One terminal transmits to the satellite on the **uplink frequency**. The satellite amplifies the signal, translates it to the downlink frequency, and then transmits it back to Earth, where the signal is picked up by the receiving terminal. Figure 2-7 illustrates the basic concept of satellite communications with several different Earth terminals.

The basic design of a satellite communications system depends a great deal on the parameters of the satellite orbit. Generally, an orbit is either elliptical or circular. Its inclination is referred to as *inclined*, *polar*, or *equatorial*. A special type of orbit is a synchronous orbit in which the period of the orbit is the same as that of the Earth's.

Two basic components make up a satellite communications system. The first is an installed communications receiver and transmitter. The second is two Earth terminals equipped to transmit and receive signals from the satellite. The design of the overall system determines the complexity of the components and the manner in which the system operates.

The U.S. Navy UHF/SHF/EHF combined communications solution allows each system to provide unique contributions to the overall naval communications needs.

The SHF spectrum is a highly desirable SATCOM medium because it possesses characteristics absent in lower frequency bands: wide operating bandwidth, narrow uplink beamwidth, low susceptibility to scintillation, anti-jam (AJ), and high data rates. Recognizing these characteristics, the U.S. Navy developed and installed shipboard SHF terminals. These attributes are discussed in the following paragraphs.

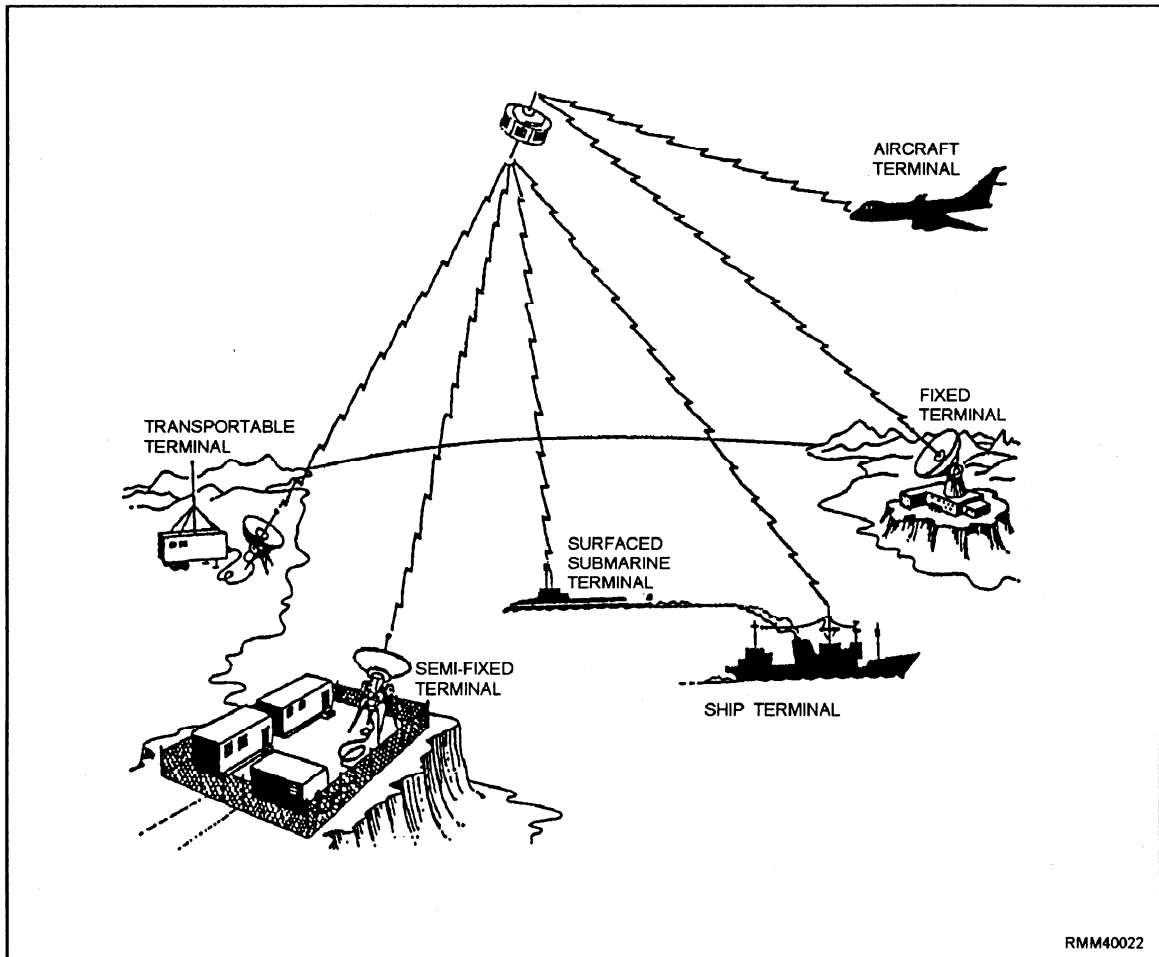


Figure 2-7.—Satellite communications systems.

Wide operating bandwidth permits high information transfer rates and facilitates spread spectrum modulation techniques. Spread spectrum modulation is a particularly valuable technique for lessening the effects of enemy jamming. Although wide bandwidth permits both high information transfer rates and AJ capabilities when using the OM-55(V)/USC modem, it may not permit both simultaneously in the presence of jamming. Therefore, high information transfer rates will be significantly reduced when jamming is encountered, permitting only certain predetermined critical circuits to be maintained.

Narrow uplink transmission beamwidth provides a low probability of intercept (LPI) capability. An uplink LPI capability reduces the threat of detection and subsequent location, but does not in and of itself deny enemy exploitation of those communications if detection is achieved. SHF frequencies are rarely affected by naturally occurring scintillation, making

SHF SATCOM a particularly reliable form of communications.

A characteristic of SHF, favorable to flagships, is the ability to communicate critical C4I for the user information in the presence of enemy jamming and with due regard for enemy detection capabilities. SURTASS Military Sealift Command Auxiliary General Ocean Surveillance (T-AGOS) ships were initially equipped with SHF SATCOM, taking advantage of the high information transfer rate capability and LPI characteristics. Because of larger available bandwidths, inherent jam-resistance, and increasing demands on limited tactical UHF SATCOM resources, additional applications for DSCS SHF SATCOM afloat are continually being investigated for the Fleet.

The radio group consists of a high power amplifier (HPA) or medium power amplifier (MPA), low noise amplifier (LNA), up-converter, down-converter, and frequency standard. For transmit operations, the up-converter translates the modem's 70 or 700

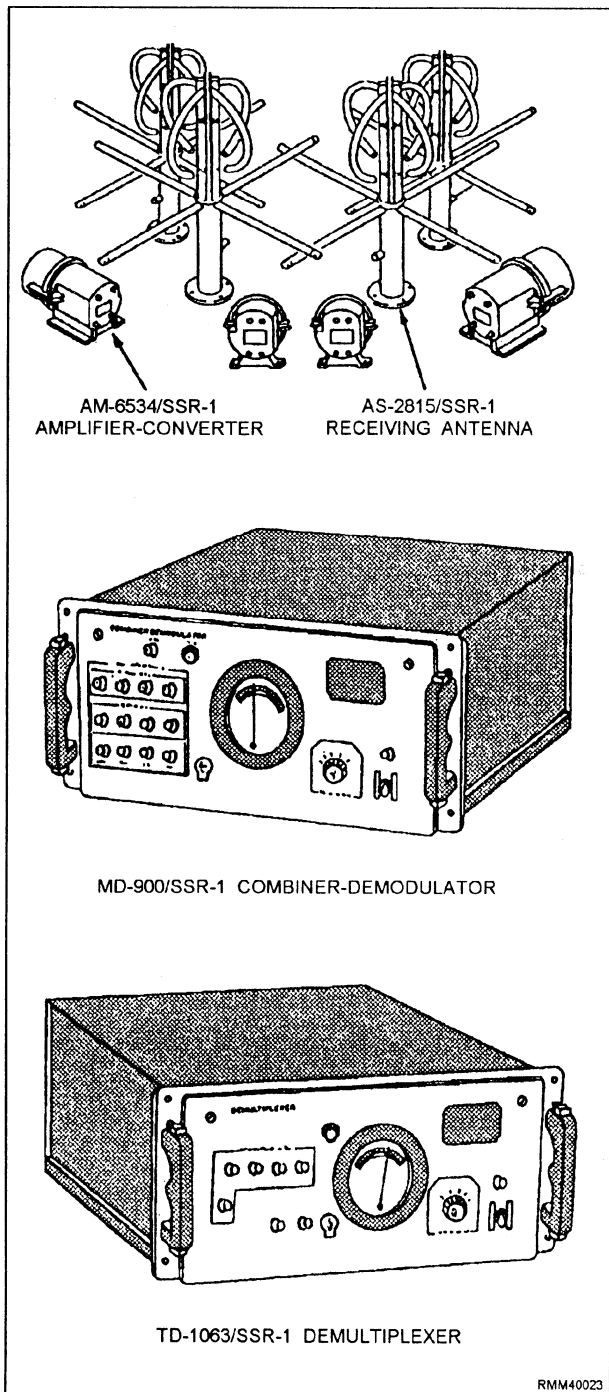


Figure 2-8.—AN/SSR-1 receiver system.

megahertz (MHz) intermediate frequency (IF) to the desired radio frequency. The signal is then passed to the HPA or MPA and amplified to its authorized power level. During receive operations, the LNA amplifies the received RF signal and sends it to the tracking converter

for antenna control and the down-converter for translation to 70 or 700 MHz IF. This signal is then sent to the modem for conversion to digital data. System frequency stability is provided by a cesium or rubidium standard.

### FLEET BROADCAST SUBSYSTEM EQUIPMENT

The SATCOM equipments that the Navy uses for the fleet broadcast include the SATCOM broadcast receiver (AN/SSR-1), the FLTSATCOM SHF broadcast transmitter (AN/FSC-79), the standard shipboard transceiver (AN/WSC-3), the shore station transceiver (AN/WSC-5), and the basic airborne transceiver (AN/ARC-143B). A brief description of these equipments is given in the next paragraphs.

The AN/SSR-1 is the Navy's standard SATCOM broadcast receiver system. This system consists of up to four AS-2815/SSR-1 antennas with an AM-6534/SSR-1 Amplifier-Converter for each antenna, an MD-900/SSR-1 Combiner-Demodulator, and a TD-1063/SSR-1 Demultiplexer (figure 2-8). The antennas are designed to receive transmissions at 240 to 315 MHz. The antennas and antenna converters are mounted above deck so that at least one antenna is always in view of the satellite. The combiner-demodulator and demultiplexer are mounted below deck.

The AN/FSC-79 Fleet Broadcast Terminal (figure 2-9) interfaces the communications subsystems and the satellite. The terminal provides the SHF uplink for the

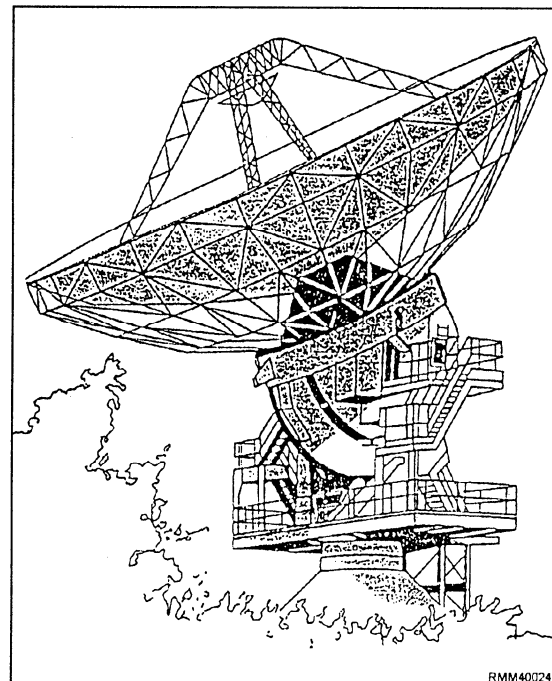


Figure 2-9.—AN/FSC-79 Fleet Broadcast Terminal.

FLTSATCOM system and is used in particular to support the Navy Fleet Broadcast system. The AN/FSC-79 operates in the 7- to 8-GHz band and is designed for single-channel operation. The AN/FSC-79 terminal is installed at the four COMMAREA master stations and NAVCOMTELSTA Stockton, Calif.

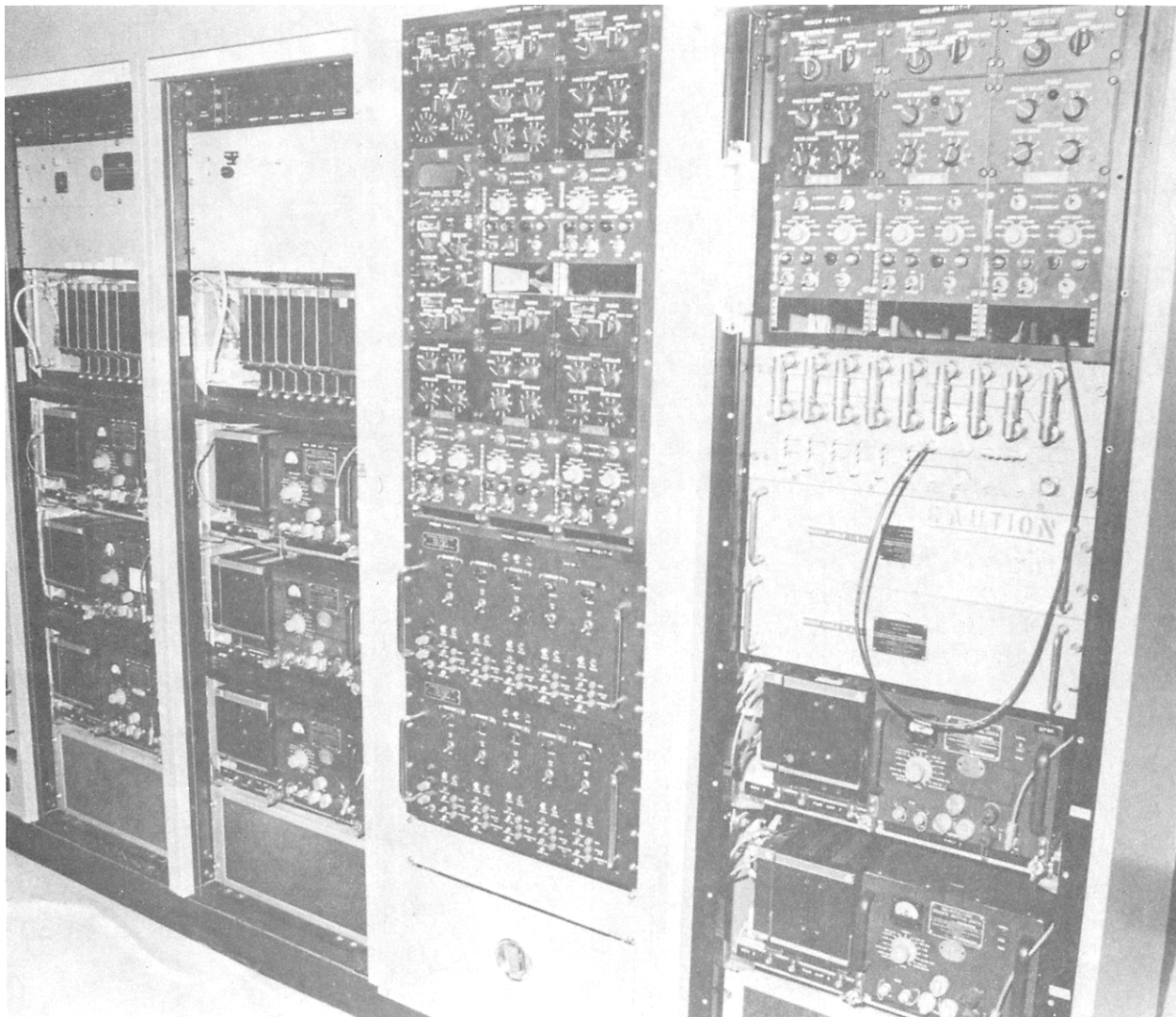
The AN/WSC-3 Transceiver is the standard UHF SATCOM transceiver for both submarine and surface ships. The AN/WSC-3 is capable of operating in either the satellite or line-of-sight (LOS) mode and can be controlled locally or remotely.

The unit is designed for single-channel, half-duplex operations in the 224- to 400-MHZ UHF band. It operates in 25-kHz increments, and has 20 preset channels. In the SATCOM mode, the AN/WSC-3 transmits (uplinks) in the 292.2- to 311.6-MHz bandwidth and receives (downlinks) in

the 248.5- to 270.1-MHz band. A separate transceiver is required for each baseband or channel use.

The AN/WSC-5 UHF Transceiver (figure 2-10) is the common UHF RF satellite terminal installed at NAVCOMTELSTAs for the GAPFILLER subsystem. In FLTSATCOM operations, it is used as the common RF terminal for all subsystems except the Fleet Satellite Broadcast (FSB) and the Antisubmarine Warfare information Exchange Subsystem (ASWIXS). The AN/WSC-5 can be used to back up the AN/FSC-79. The AN/WSC-5 transmits in the 248.5- to 312-MHz range and receives in the 248.5- to 270.1-MHz range.

The AN/ARC-143 UHF Transceiver (figure 2-11) is used for ASWIXS communications and is installed at VP Antisubmarine Warfare Operation Centers and aboard P-3C aircraft. The unit two parts: a transceiver and a radio set control. The AN/ARC-143



**Figure 2-10.—AN/WSC-5 UHF Transceiver.**

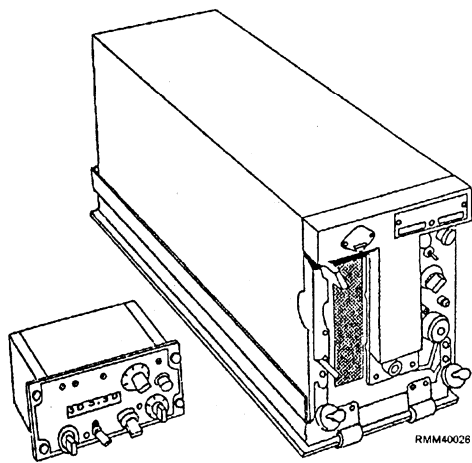


Figure 2-11.—AN/ARC-143 UHF Transceiver.

can be used to transmit or receive voice or data in the 255.0- to 399.99-MHz frequency range.

The systems discussed are only a few of the SATCOM equipments used by the Navy. Some of the references listed in Appendix III of this module are excellent sources for more information on satellite equipment and systems.

### FLEET SATELLITE COMMUNICATIONS SYSTEM AND SUBSYSTEMS

The Fleet Satellite Communications (FLTSATCOM) system and subsystems provide communications links, via satellite, between shore commands and mobile units. The system includes RF terminals, subscriber subsystems, training, documentation, and logistic support. Within each

satellite, the RF channels available for use have been distributed between the Navy and the Air Force.

Equipments in support of the FLTSATCOM system are on ships, submarines, aircraft, and at shore stations. These equipment installations vary in size and complexity. Furthermore, with the exception of voice communications, the system applies the technology of processor- (computer-) controlled RF links and uses the assistance of processors in message traffic preparation and handling.

Although any part of the FLTSATCOM system can be operated as a separate module, system integration provides connections for message traffic and voice communications to DOD communications networks.

A backup capability that can be used in the event of an outage or equipment failure is provided for both shore and afloat commands. All subsystems have some form of backup mode, either from backup equipment and/or systems, facilities, or RF channels. This capability is built in as part of the system design and may limit the ability of selected FLTSATCOM systems to process information.

### FLEET SATELLITE BROADCAST (FSB) SUBSYSTEM

The Fleet Satellite Broadcast (FSB) subsystem is an expansion of fleet broadcast transmissions that historically have been the central communications medium for operating naval units. The FSB transmits messages, weather information, and intelligence data to ships. The shore terminal transmits this data on a direct SHF signal to a satellite, where the signal is translated to UHF and downlinked. Figure 2-12 shows a standard FSB subsystem configuration.

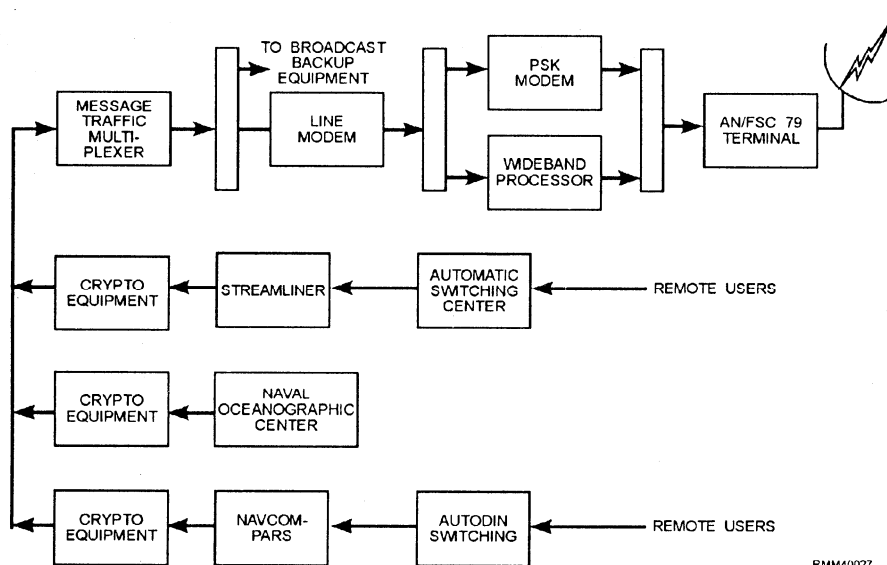


Figure 2-12.—Fleet Satellite Broadcast subsystem.

**COMMON USER DIGITAL INFORMATION EXCHANGE SYSTEM (CUDIXS) AND NAVAL MODULAR AUTOMATED COMMUNICATIONS SYSTEM (NAVMACS)**

The CUDIXS/NAVMACS combine to form a communications network that is used to transmit general service (GENSER) message traffic between ships and shore installations. NAVMACS serves as an automated shipboard terminal for interfacing with CUDIXS (shore-based) (figure 2-13) and the Fleet Broadcast System.

**OTHER SPECIALIZED SUBSYSTEMS**

The FLTSATCOM system represents a composite of information exchange subsystems that use the satellites as a relay for communications. The following subsystems satisfy the unique communication requirements for each of the different naval communities.

- **Submarine Satellite Information Exchange Subsystem (SSIXS)**

The SSIXS provides a communications system to exchange message traffic between SSBN and SSN submarines and shore stations.

- **Antisubmarine Warfare Information Exchange Subsystem (ASWIXS)**

ASWIXS is designed as a communications link for antisubmarine warfare (ASW) operations between shore stations and aircraft.

- **Tactical Data Information Exchange Subsystem (TADIXS)**

TADIXS is a direct communications link between command centers ashore and afloat. TADIXS provides one-way transmission of data link communications.

- **Secure Voice Subsystem**

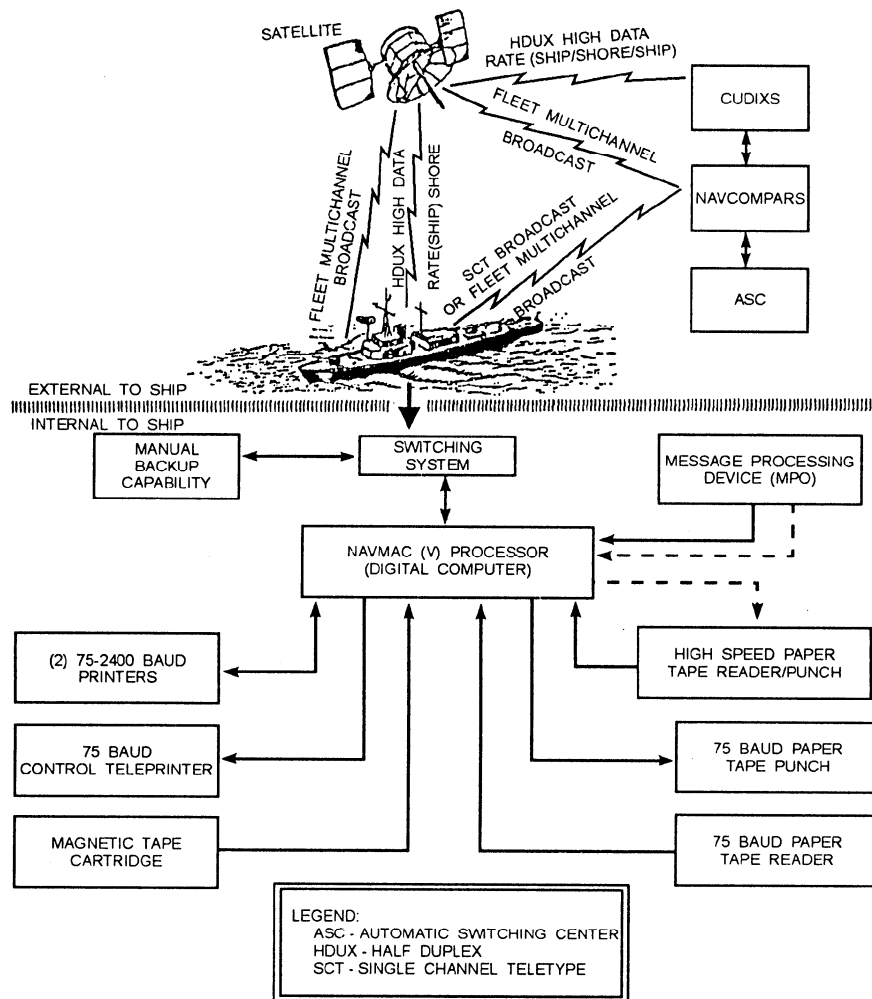


Figure 2-13.—NAVMACS (V) communications interface.



The secure voice subsystem is a narrowband UHF link that enables secure voice communications between ships. It also allows, connection with wide-area voice networks ashore.

- **Tactical Intelligence (TACINTEL) Subsystem**

TACINTEL is specifically designed for special intelligence communications.

- **Control Subsystem**

The Control subsystem is a communications network that facilitates status reporting and management of FLTSATCOM system assets.

- **Officer in Tactical Command Information Exchange Subsystem (OTCIIXS)**

OTCIIXS is designed as a communications link for battle group tactical operations.

- **Teleprinter Subsystem (ORESTES)**

ORESTES is an expansion of the existing teleprinter transmission network.

## **LEASAT TELEMETRY TRACKING AND COMMAND SUBSYSTEM**

The LEASAT Telemetry Tracking and Command subsystem is a joint operation between the U.S. Navy and contractors for controlling LEASATS. The installation of subsystem baseband equipment and RF terminals aboard ships and aircraft is determined by communications traffic levels, types of communications, and operational missions.

Since Fleet Satellite Broadcast message traffic is a common denominator for naval communications, it is received by numerous types of ships. In some installations, such as large ships, the fleet broadcast receiver represents one part of the FLTSATCOM equipment suite. A typical configuration on a large ship would include fleet broadcast, CUDIXS/NAVMACS, secure voice, OTCIIXS, TADIXS, teleprinter, and TACINTEL equipment.

The FLTSATCOM subsystems apply some form of automated control to the communications being transmitted with the exception of the secure voice and control subsystems. This includes message or data link processing before and after transmittal and control of the RF network (link control) in which the messages are being transmitted. The automation of these functions is handled by a processor.

Much of the message processing before transmission and after receipt is fully automatic and does not require operator intervention. The actual message or data link transmission is fully automated and under the control of a processor. Within the limitations of equipment capability, each subsystem addresses the unique requirements of the user and the environment in which the user operates.

## **DEMAND ASSIGNED MULTIPLE ACCESS (DAMA)**

DAMA was developed to multiplex several subsystems or users on one satellite channel. This arrangement allows more satellite circuits to use each UHF satellite channel.

### **Multiplexing**

The number of communications networks being used is constantly increasing. As a result, all areas of the RF spectrum have become congested. Multiplexing is a method of increasing the number of transmissions taking place in the radio spectrum per unit of time.

Multiplexing involves the simultaneous transmission of a number of intelligible signals using only a single transmitting path. As we mentioned earlier, the Navy uses two multiplexing methods: time-division multiplexing (TDM) and frequency-division multiplexing (FDM). We have already discussed FDM with the AN/UCC-1. Additional information concerning both methods can be found in *Radio-Frequency Communication Principles*, NEETS, Module 17.

A UHF DAMA subsystem, the TD-1271/U Multiplexer, was developed to provide adequate capacity for the Navy and other DOD users. This subsystem was developed to multiplex (increase) the number of subsystems, or users, on 1 25-kHz satellite channel by a factor of 4.

This factor can be further increased by multiples of 4 by patching 2 or more TD-1271s together. This method increases the number of satellite circuits per channel on the UHF satellite communications system. Without this system, each satellite communications subsystem would require a separate satellite channel.

### **Transmission Rates**

The DAMA equipment accepts encrypted data streams from independent baseband sources and combines them into one continuous serial output data

stream. DAMA was designed to interface the Navy UHF SATCOM baseband subsystem and the AN/WSC-5 and AN/WSC-3 transceivers.

The TD-1271/U Multiplexer includes a modem integral to the transceiver. The baseband equipment input or output data rate with DAMA equipment can be 75, 300, 600, 1,200, 2,400, 4,800, or 16,000 bits per second (bps). The DAMA transmission rate on the satellite link (referred to as “burst rate”) can be 2,400, 9,600, 19,200, or 32,000 symbols per second.

### **Circuit Restoral/Coordination**

When a termination is lost in either or both directions, communications personnel must observe special guidelines. During marginal or poor periods of communications, the supervisors should assign a dedicated operator to the circuit if possible.

When normal circuit restoration procedures are unsuccessful and/or a complete loss of communications exists, an IMMEDIATE precedence COMMSPOT message should be transmitted (discussed earlier). Every means available must be used to re-establish the circuit, including messages, support from other ships or NAVCOMTELSTAs, or coordination via DAMA if available.

The guidelines established in NTP 4, CIBs, and local SOPs are not intended to suppress individual initiative in re-establishing lost communications. Circuit restoral is dependent upon timely action, quick decisions, and the ability of personnel to use any means available to restore communications in the shortest possible time.

### **SPECIAL CIRCUITS**

During certain communications operations, you may be required to activate and operate special circuits. Some of the most common special circuits are discussed next.

#### **UHF AUTOCAT/SATCAT/MIDDLEMAN RELAY CIRCUITS**

Shipboard HERO conditions and emission control (EMCON) restrictions often prohibit transmission of RF below 30 MHz.

To provide an uninterrupted flow of essential communications without violating HERO and EMCON restrictions, AUTOCAT, SATCAT, and MIDDLEMAN were developed. With these techniques, the range of

tactical UHF circuits (voice or teleprinter) can be extended by relay of AM UHF transmissions via HF or satellite. AUTOCAT accomplishes this using a ship; whereas SATCAT uses an airborne platform for automatically relaying UHF transmissions. MIDDLEMAN requires an operator to copy the messages with subsequent manual retransmission.

The three techniques just discussed use three different types of circuit for reception and relay of UHF transmissions. These circuits are as follows:

- A voice circuit where some units send and receive on one frequency, and other units send and receive on any other frequency;
- A voice circuit where all units transmit on one frequency and receive on another frequency; and
- A RATT circuit where all units transmit on one frequency and receive on another frequency.

### **FLEET FLASH NET**

The Fleet Flash Net (FFN) is composed of senior operational staffs and other designated subscribers. The purpose of the FFN is to distribute high-precedence or highly sensitive traffic among subscribers. A receipt on the net constitutes firm delivery, and the message need not be retransmitted over other circuits to receiving stations. The FFN is explained in more detail in *Mission Communications*, NTP 11.

### **ANTENNA SYSTEMS**

Operation of communication equipment over the entire range of the RF spectrum requires many types of antennas. You will need to know the basic type of antennas available to you operationally, their characteristics, and their uses. Very often, you, the operator, can mean the difference between efficient and inefficient communications. You will have a choice of many antennas and must select the one most suitable for the task at hand. Your operational training will acquaint you with the knowledge necessary to properly use the antennas at your disposal. However, your operational training **WILL NOT** acquaint you with the **WHY** of antennas, in other words, basic antenna theory. The following topics are intended to familiarize you with basic antenna terminology, definitions, and characteristics.

## ANTENNA CHARACTERISTICS

As you will learn in this section, all antennas exhibit common characteristics. The study of antennas involves the following terms with which you must become familiar:

### Antenna Reciprocity

The ability of an antenna to both transmit and receive electromagnetic energy is known as its reciprocity. Antenna reciprocity is possible because antenna characteristics are essentially the same for sending and receiving electromagnetic energy.

Even though an antenna can be used to transmit or receive, it cannot be used for both functions at the same time. The antenna must be connected to either a transmitter or a receiver.

### Antenna Feed Point

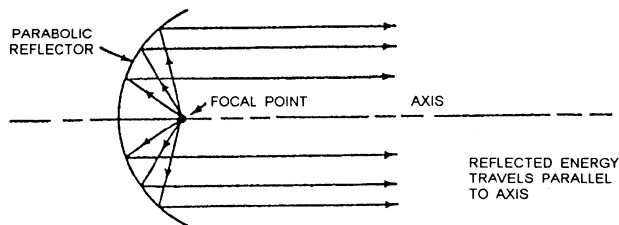
**Feed point** is the point on an antenna where the RF cable is attached. If the RF transmission line is attached to the base of an antenna, the antenna is **end-fed**. If the RF transmission line is connected at the center of an antenna, the antenna is **mid-fed** or **center-fed**.

### Directivity

The **directivity** of an antenna refers to the width of the radiation beam pattern. A directional antenna concentrates its radiation in a relatively narrow beam. If the beam is narrow in either the horizontal or vertical plane, the antenna will have a high degree of directivity in that plane. An antenna can be highly directive in one plane only or in both planes, depending upon its use.

In general, we use three terms to describe the type of directional qualities associated with an antenna: **omnidirectional**, **bidirectional**, and **unidirectional**. Omnidirectional antennas radiate and receive equally well in all directions, except off the ends. Bidirectional antennas radiate or receive efficiently in only two directions. Unidirectional antennas radiate or receive efficiently in only one direction.

Most antennas used in naval communications are either omnidirectional or unidirectional. Bidirectional antennas are rarely used. Omnidirectional antennas are used to transmit fleet broadcasts and are used aboard ship for medium-to-high frequencies. A parabolic, or dish, antenna (figure 2-14) is an example of a unidirectional antenna. As you can see in the figure, an



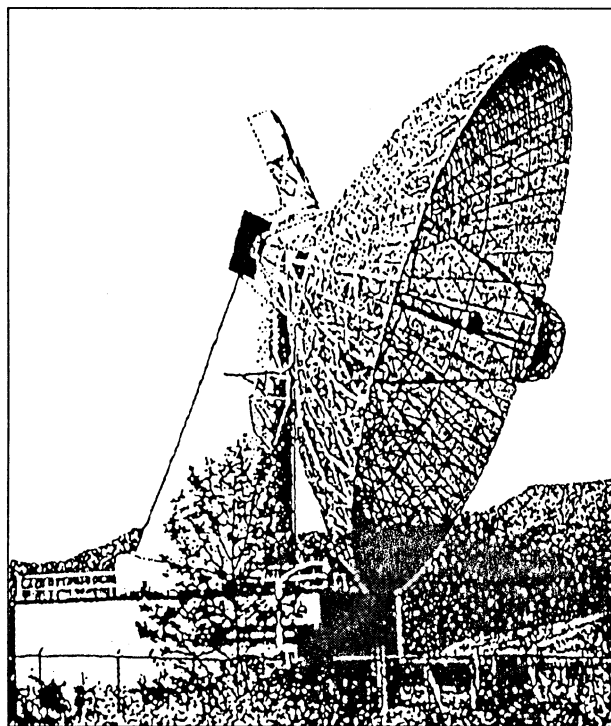
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Figure 2-14.—Principle of parabolic reflection.

antenna (normally a half wave) is placed at the “focal” point and radiates the signal back into a large reflecting surface (the dish). The effect is to transmit a very narrow beam of energy that is essentially unidirectional. Figure 2-15 shows a large, unidirectional parabolic antenna. Directional antennas are commonly used at shore installations.

### Wave Polarization

Polarization of a radio wave is a major consideration in the efficient transmission and reception of radio signals. If a single-wire antenna is



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Figure 2-15.—Unidirectional parabolic antenna.

used to extract energy from a passing radio wave, maximum signal pickup results when the antenna is placed physically in the same direction as the electric field component. For this reason, a vertical antenna is used to receive vertically polarized waves, and a horizontal antenna is used to receive horizontally polarized waves.

At lower frequencies, wave polarization remains fairly constant as it travels through space. At higher frequencies, the polarization usually varies, sometimes quite rapidly. This is because the wave front splits into several components, and these components follow different propagation paths.

When antennas are close to the ground, vertically polarized radio waves yield a stronger signal close to the Earth than do those that are horizontally polarized. When the transmitting and receiving antennas are at least one wavelength above the surface, the two types of polarization are approximately the same in field intensity near the surface of the Earth. When the transmitting antenna is several wavelengths above the surface, horizontally polarized waves result in a stronger signal close to the Earth than is possible with vertical polarization.

Most shipboard communication antennas are vertically polarized. This type of polarization allows the antenna configuration to be more easily accommodated in the limited space allocated to shipboard communications installations. Vertical antenna installations often make use of the topside structure to support the antenna elements. In some cases, to obtain the required impedance match between the antenna base terminal and transmission line, the structure acts as part of the antenna.

VHF and UHF antennas used for ship-to-aircraft communications use both vertical and circular polarization. Because aircraft maneuvers cause cross-polarization effects, circularly polarized shipboard antennas frequently offer considerable signal improvements over vertically polarized antennas.

Circularly polarized antennas are also used for ship-to-satellite communications because these antennas offer the same improvement as VHF/UHF ship-to-aircraft communications operations. Except for the higher altitudes, satellite antenna problems are similar to those experienced with aircraft antenna operations.

### Standing Wave Ratio

Another term used in antenna tuning is standing wave ratio (SWR), also called voltage standing wave

ratio (VSWR). A simple definition could be the “relative degree of resonance” achieved with antenna tuning. When tuning an antenna, you must understand the SWR when expressed numerically.

You will hear SWR expressed numerically in nearly every tuning procedure. For example, you will hear such terms as “three-to-one,” or “two-to-one.” You will see them written 3:1 SWR, 2:1 SWR, or 1:1 SWR. The **lower** the number ratio is, the **better** the match between the antenna and the transmitter for transmitting RF signals. For example, a 2:1 SWR is better than a 3:1 SWR.

As you approach resonance, you will notice that your SWR figure on the front panel meters will begin to drop to a lower numerical value. A good SWR is considered to be 3 or below, such as 3:1 or 2:1. Anything over 3, such as 4:1, 5:1, or 6:1 is unsatisfactory. The SWR becomes increasingly critical as transmitter output is increased. Where a 3:1 SWR is satisfactory with a 500-watt transmitter, a 2:1 SWR may be considered satisfactory with a 10-kilowatt transmitter.

Most antenna couplers have front panel meters that show a readout of the relative SWR achieved via antenna tuning. Figure 2-16 shows a multicoupler,

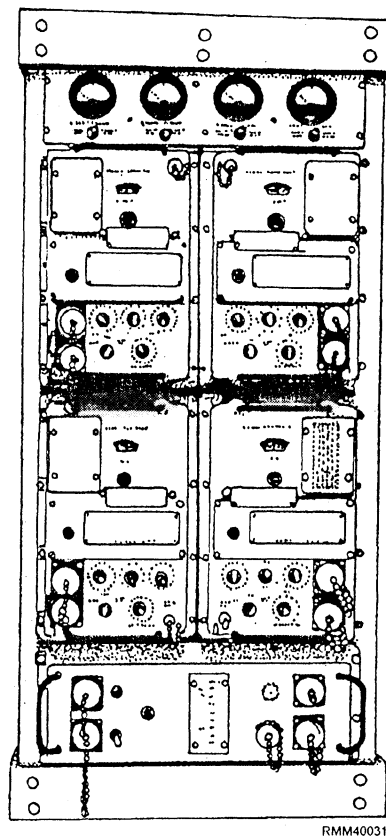


Figure 2-16.—AN/SRA-33 antenna multicoupler.

consisting of four coupling units, with four SWR meters at the top (one for each coupler).

To achieve a perfect standing wave ratio of 1:1 would mean that we have succeeded in tuning out all other impedances and that the antenna is matched perfectly to the transmitted frequency. With such a low SWR, the antenna would now offer only its characteristic impedance. A 1:1 SWR is rarely achieved, of course. There will always be some power loss between the transmitter and the antenna because of natural impedances that exist between the two. Nevertheless, the objective is to achieve the lowest SWR possible. In other words, we want only the characteristic impedance of the antenna remaining.

### Incident Waves

Various factors in the antenna circuit affect the radiation of RF energy. When we energize or feed an antenna with an alternating current (ac) signal, waves of energy are created along the length of the antenna. These waves, which travel from a transmitter to the end of the antenna, are the incident waves.

Let's look at figure 2-17. If we feed an ac signal at point A, energy waves will travel along the antenna until they reach the end (point B). Since the B end is free, an open circuit exists and the waves cannot travel farther. This is the **point of high impedance**. The energy waves bounce back (reflect) from this point of high impedance and travel toward the feed point, where they are again reflected.

### Reflected Waves

We call the energy reflected back to the feed point the **reflected wave**. The resistance of the wire gradually decreases the energy of the waves in this back-and-forth motion (oscillation). However, each time the waves reach the feed point (point A of figure 2-17), they are reinforced by enough power to replace

the lost energy. This results in continuous oscillations of energy along the wire and a high voltage at point A on the end of the wire. These oscillations are applied to the antenna at a rate equal to the frequency of the RF voltage.

In a perfect antenna system, all the energy supplied to the antenna would be radiated into space. In an imperfect system, which we use, some portion of the energy is reflected back to the source with a resultant decrease in radiated energy. The more energy reflected back, the more inefficient the antenna. The condition of most antennas can be determined by measuring the power being supplied to the antenna (forward power) and the power being reflected back to the source (reflected power). These two measurements determine the voltage standing wave ratio (VSWR), which indicates antenna performance.

If an antenna is resonant to the frequency supplied by the transmitter, the reflected waves and the incident waves are in phase along the length of the antenna and tend to reinforce each other. It is at this point that radiation is maximum, and the SWR is best. When the antenna is not resonant at the frequency supplied by the transmitter, the incident and reflected waves are out of phase along the length of the antenna and tend to cancel out each other. These cancellations are called power losses and occur when the SWR is poor, such as 6:1 or 5:1.

Most transmitters have a long productive life and require only periodic adjustment and routine maintenance to provide maximum operating efficiency and reliable communications. Experience has shown that many of the problems associated with unreliable radio communication and transmitter failures can be attributed to high antenna VSWR.

### Dummy Loads

Under radio silence conditions, placing a carrier on the air during transmitter tuning would give an enemy the opportunity to take direction-finding bearings and determine the location of the ship. Even during normal periods of operation, transmitters should be tuned by methods that do not require radiation from the antenna. This precaution minimizes interference with other stations using the circuit.

A dummy load (also called dummy antenna) can be used to tune a transmitter without causing unwanted radiation. Dummy loads have resistors that dissipate the RF energy in the form of heat and prevent radiation by the transmitter during the tuning operation. The

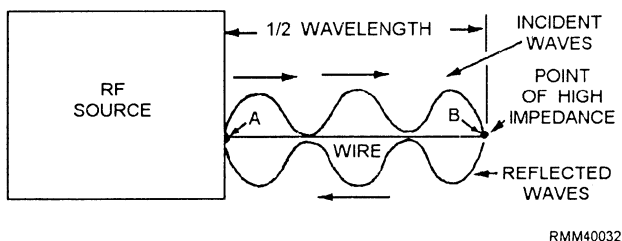


Figure 2-17.—Incident and reflected waves on an antenna.

dummy load, instead of the antenna, is connected to the output of the transmitter, and the normal transmitter tuning procedure is followed.

Most Navy transmitters have a built-in dummy load. This permits you to switch between the dummy load or the actual antenna, using a switch. For transmitters that do not have such a switch, the transmission line at the transmitter is disconnected and connected to the dummy load (figure 2-18). When transmitter tuning is complete, the dummy load is disconnected and the antenna transmission line is again connected to the transmitter.

## ELECTROMAGNETIC WAVELENGTH

Electromagnetic waves travel through free space at 186,000 miles per second. But, because of resistance, the travel rate of these waves along a wire is slightly slower. An antenna must be an appropriate length so that a wave will travel from one end to the other and return to complete one cycle of the RF voltage. A wavelength is the distance traveled by a radio wave in one cycle. This means that wavelength will vary with frequency.

If we increase the frequency, the time required to complete one cycle of alternating current (ac) is naturally less; therefore, the wavelength is less. If we decrease the frequency, the time required to complete one cycle of ac is longer; therefore, the wavelength is longer. Another word used to represent wavelength is LAMBDA (designated by the symbol  $\lambda$ ).

The term "wavelength" also refers to the length of an antenna. Antennas are often referred to as **half wave**, **quarter wave**, or **full wave**. These terms describe the

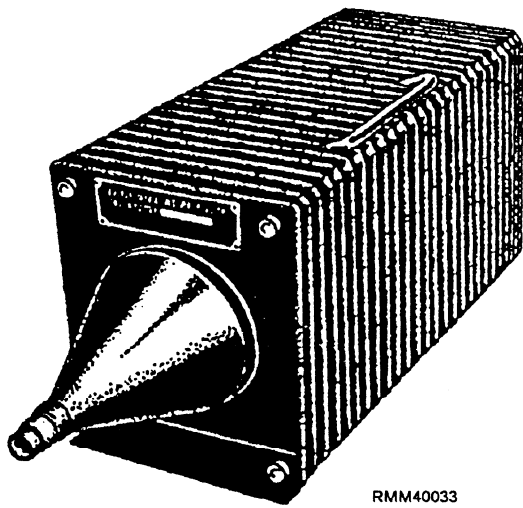


Figure 2-18.—DA-91/U dummy load.

relative length of an antenna, whether that length is electrical or physical.

Earlier, we said that when tuning an antenna, we are electrically lengthening or shortening the antenna to achieve resonance at that frequency. We are actually changing the wavelength of the antenna. The electrical length of an antenna may not be the same as its physical length.

You know that RF energy travels through space at the speed of light. However, because of resistance, RF energy on an antenna travels at slightly less than the speed of light. Because of this difference in velocity, the physical length no longer corresponds to the electrical length of an antenna. Therefore, an antenna may be a half-wave antenna electrically, but it is physically somewhat shorter. For information on how to compute wavelengths for different frequencies, consult NEETS, Module 12, *Modulation Principles*.

## BASIC ANTENNAS

Many types and variations of antenna design are used in the fleet to achieve a particular directive radiation pattern or a certain vertical radiation angle. However, all antennas are derived from two basic types: the half wave and the quarter wave.

### HALF-WAVE ANTENNA

An antenna that is one-half wavelength long is the shortest antenna that can be used to radiate radio signals into free space. The most widely used antenna is the half-wave antenna, commonly called a dipole, or hertz, antenna. This antenna consists of two lengths of wire rod, or tubing, each one-fourth wavelength long at a certain frequency.

Many complex antennas are constructed from this basic antenna design. This type of antenna will not function efficiently unless its length is one-half wavelength of the frequency radiated or received.

Figure 2-19 shows a theoretical half-wave antenna with a center feed point. Both sections of the antenna

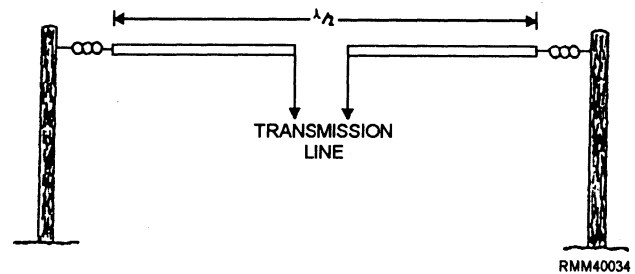


Figure 2-19.—Half-wave antenna with center feed point.

are  $\lambda/4$  (one-fourth wavelength) at the operating frequency. Together, of course, the sections make the effective length of the antenna  $\lambda/2$  (one-half wavelength) at the operating frequency.

One feature of the dipole antenna is that it does not need to be connected to the ground like other antennas. Antennas shorter than a half wavelength must use the ground to achieve half-wave characteristics. The half-wave antenna is already long enough to radiate the signal properly.

Because of sophisticated antenna systems and tuning processes, half-wave antennas can be electrically achieved aboard ship. Therefore wavelength is becoming less and less the criteria for determining the types of antennas to be used on ships. Dipole antennas can be mounted horizontally or vertically, depending upon the desired polarization, and can be fed at the center or at the ends. Because it is ungrounded, the dipole antenna can be installed above energy-absorbing structures.

### QUARTER-WAVE ANTENNA

A quarter-wave antenna is a grounded antenna that is one-fourth wavelength of the transmitted or received frequency. You will hear the quarter-wave antenna referred to as a "Marconi antenna." The quarter-wave antenna is also omnidirectional.

As we mentioned earlier, a half-wave antenna is the shortest practical length that can be effectively used to radiate radio signals into free space. The natural question, then is, "How do we use a quarter-wavelength antenna if a half-wavelength is the shortest length that can be used?" The answer is simple.

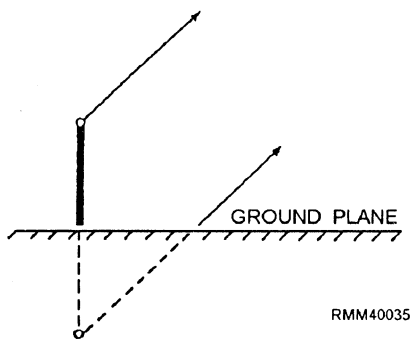


Figure 2-20.—Direct and image signal of a quarter-wave antenna.

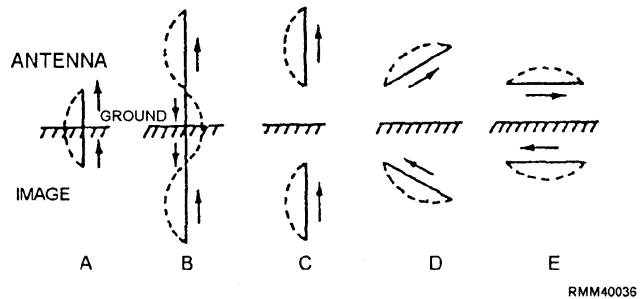


Figure 2-21.—Current distribution in a real antenna and its image.

Two components make up the total radiation from an antenna. One component is that part of the radiated signal which leaves the antenna directly. The other is a **ground reflection** that appears to come from an underground image of the real antenna (figure 2-20). This image is sometimes called the **mirror image** and is considered to be as far below the ground as the real antenna is above it.

Figure 2-21 shows basic current distribution in a real and image antenna. There are certain directions in which the direct wave from the real antenna and the reflected wave from the image are exactly equal in amplitude but opposite in phase. Conversely, there are other directions in which the direct and reflected waves are equal in amplitude and in phase. Therefore, depending on the direction and location of the point at which the field strength is measured, the actual field strength may be (1) twice the field strength from the real antenna alone, (2) zero field strength, or (3) some intermediate value between maximum and minimum. It is this "real" and "image" radiated field that forms the basis for using quarter-wavelength antennas.

This reflected-energy principle is very useful in the lower frequency ranges, although ground reflections occur in the high-frequency range as well.

The antenna does not always need to be placed at the Earth's surface to produce an image. Another method of achieving reflected images is through the use of ground planes. This means that a large reflecting metallic surface is used as a substitute for the ground or Earth. This method is frequently used in the VHF/UHF

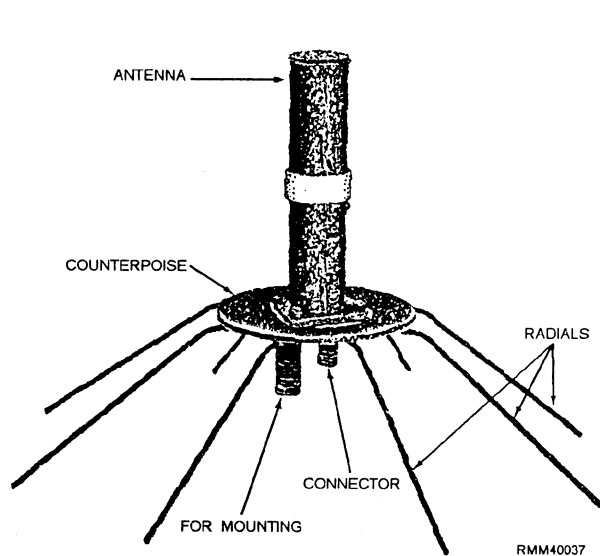


Figure 2-22.—AS-390/SRC UHF antenna with counterpoise, or ground plane.

frequency ranges. Figure 2-22 shows a commonly used UHF antenna (AS-390/SRC), which uses this principle. The ground plane is sometimes referred to as a “counterpoise,” as shown in the figure. Together, the counterpoise and the radials form the reflecting surface, which provides the reflected image.

### TYPES OF SHIPBOARD ANTENNAS

Figure 2-23 shows various shipboard antennas and their placements. The complex structures of modern ships and their operational requirements require the use of many types of antenna. These types include wire

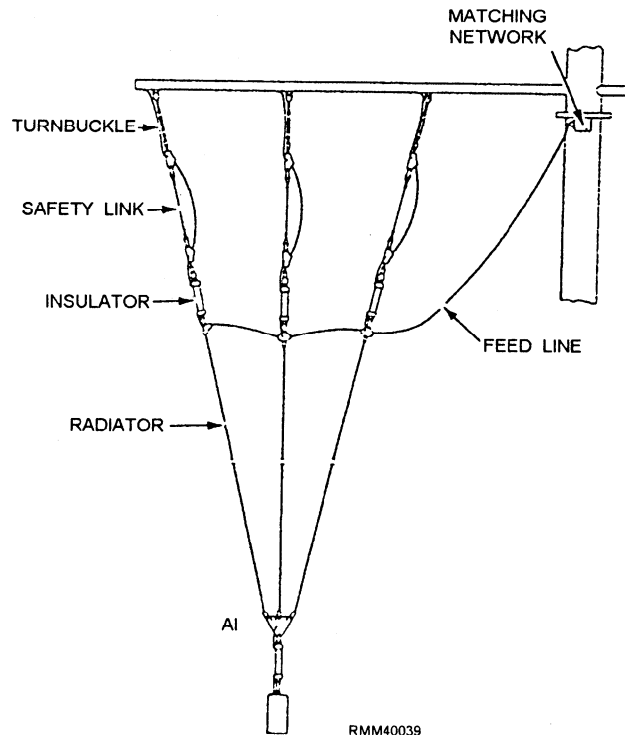


Figure 2-24.—Wire rope fan antenna.

rope fans, whips, cages, dipoles, probes, trussed monopoles, and bow stubs. The selection and use of different types is often governed by the limited space available.

### WIRE ROPE ANTENNAS

Wire rope antennas are installed aboard ship for medium- and high-frequency (300 kHz to 30 MHz) coverage. A wire rope antenna (figure 2-24) consists of

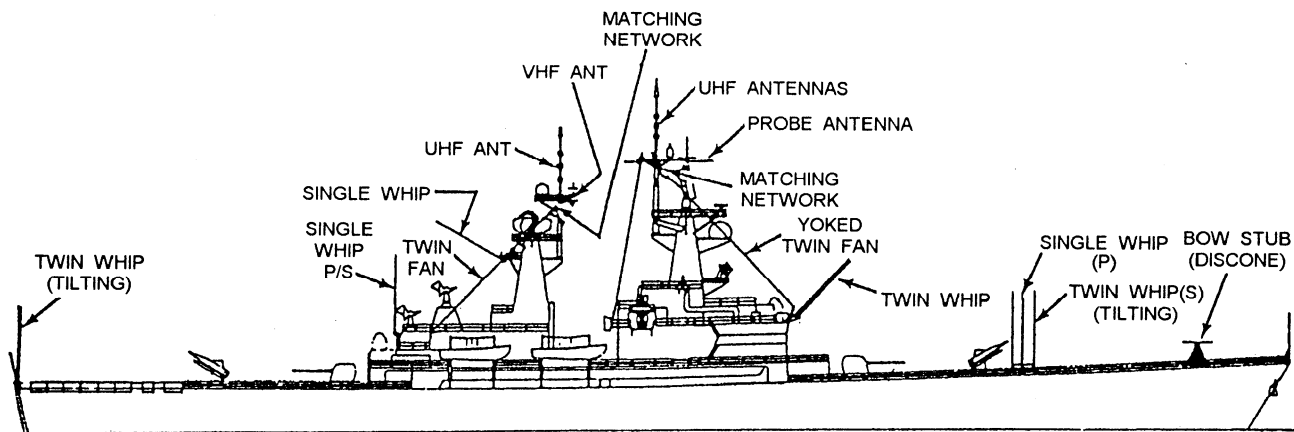


Figure 2-23.—Shipboard antenna systems.



one or more lengths of flexible wire rigged from two or more points on the ship's superstructure. A wire rope antenna is strung either vertically or horizontally from a yardarm or mast to outriggers, another mast, or to the superstructure. If used for transmitting, the wire antenna is tuned electrically to the desired frequency.

Receiving wire antennas are normally installed forward on the ship, rising nearly vertically from the pilothouse top to brackets on the mast or yardarm. Receiving antennas are located as far as possible from the transmitting antennas so that a minimum of energy is picked up from local transmitters.

Because of the characteristics of the frequency range in which wire antennas are used, the ship's superstructure and other nearby structures become an electronically integral part of the antenna. As a result, wire rope antennas are usually designed or adapted specifically for a particular ship.

### WHIP ANTENNAS

Whip antennas are used for medium- and high-frequency transmitting and receiving systems. For low-frequency systems, whip antennas are used only for receiving. Essentially self-supporting, whip antennas may be deck-mounted or mounted on brackets on the stacks or superstructure. The self-supporting feature of the whip makes it particularly useful where space is limited and in locations not suitable for other types of antennas. Whip antennas can be tilted, a design feature that makes them suited for use along the edges of aircraft carrier flight decks. Aboard submarines, they can be retracted into the sail structure.

Whip antennas commonly used aboard ship are 25, 28, or 35 feet long and consist of several sections. The 35-foot whip is most commonly used. If these antennas are mounted less than 25 feet apart, they are usually connected with a crossbar with the feed point at its center. The twin whip antenna (figure 2-25) is not broadband and is generally equipped with a base tuning unit.

### VHF AND UHF ANTENNAS

The physical size of VHF and UHF antennas is relatively small because of the short wavelengths at these frequencies. Aboard ship, these antennas are installed as high and as much in the clear as possible.

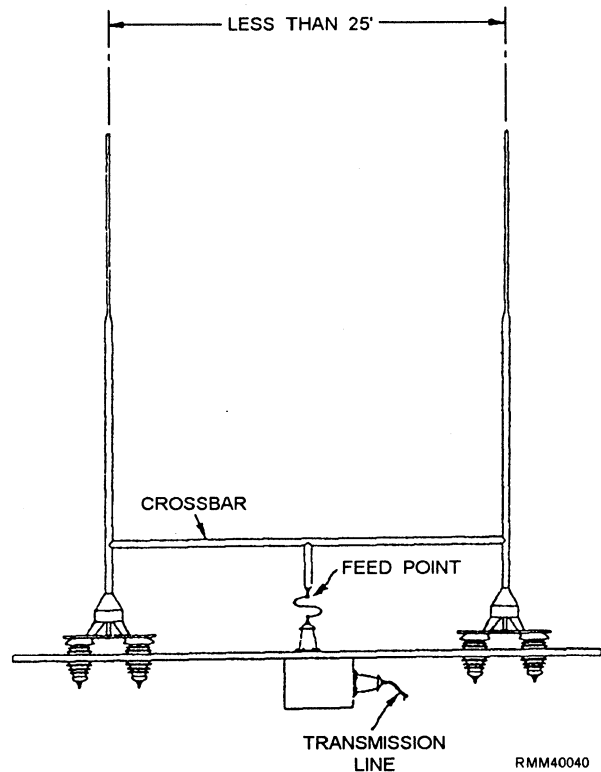


Figure 2-25.—Twin whip antenna with crowbar.

Since VHF and UHF antennas are line-of-sight systems, they require a clear area at an optimum height on the ship structure or mast. Unfortunately, this area is also needed for various radars and UHF direction-finding and navigational aid systems.

VHF and UHF antennas are usually installed on stub masts above the foremast and below the UHF direction finder. UHF antennas are often located on the outboard ends of the yardarms and on other structures that offer a clear area.

For best results in the VHF and UHF ranges, both transmitting and receiving antennas must have the same polarization. Vertically polarized antennas are used for all ship-to-ship, ship-to-shore, and ground-to-air VHF/UHF communications. Usually, either a vertical half-wave dipole or a vertical quarter-wave antenna with ground plane is used. An example of a UHF half-wave (dipole) antenna is the AT-150/SRC, shown in

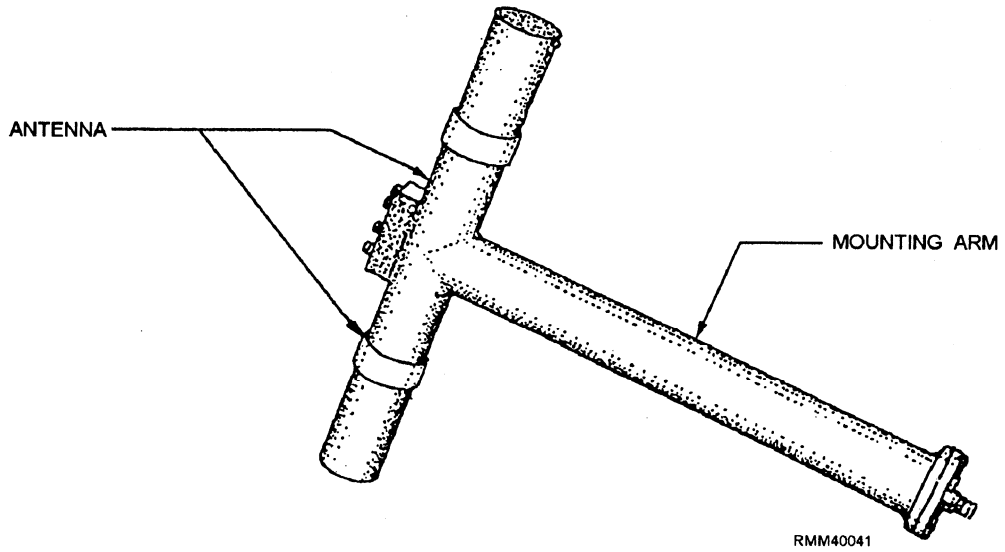


Figure 2-26.—AT-150/SRC UHF antenna.

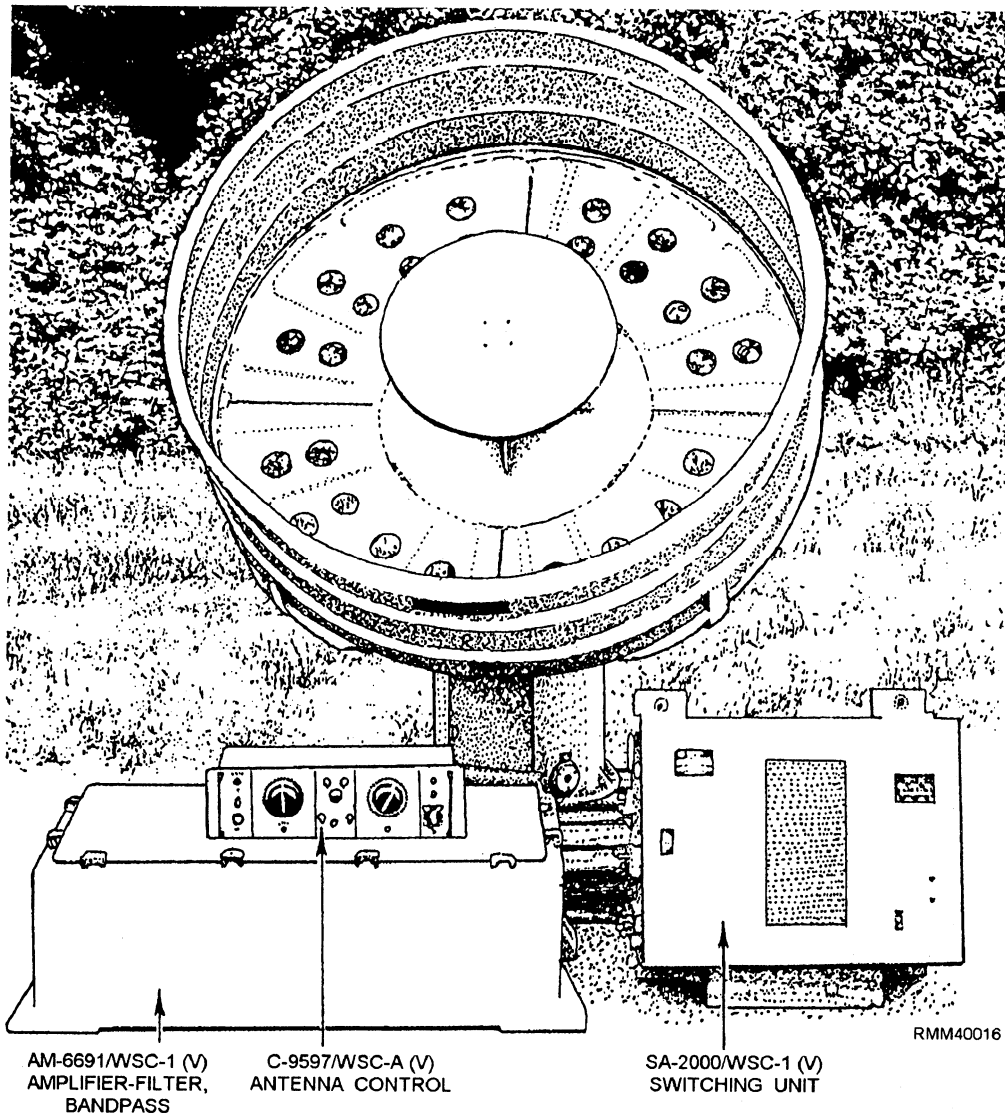


Figure 2-27.—OE-82C/WSC-1(V) antenna group.

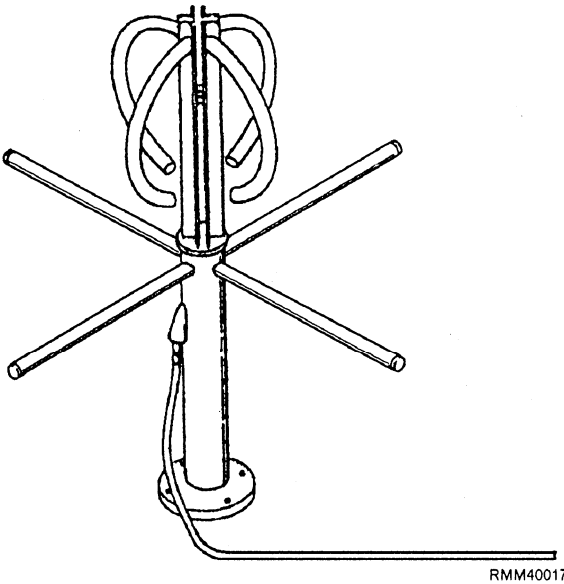


Figure 2-28.—AS-2815/SSR-1 antenna physical configuration.

Figure 2-26. This antenna is normally mounted horizontally.

### BROADBAND ANTENNAS

Broadband antennas for HF and UHF bands have been developed for use with antenna multicouplers. Therefore, several circuits may be operated with a single antenna. Broadband antennas must be able to transmit or receive over a wide frequency band.

HF broadband antennas include the 35-foot twin and trussed whips, half-cone, cage, and a variety of fan-

designed antennas. The AT-150/SRC UHF antenna in figure 2-26 is an example of a broadband antenna.

### SATCOMM ANTENNAS

The antennas shown in figures 2-27 and 2-28 are used for satellite communications. The 0E-82C/WSC-1(V) antenna (figure 2-27) is used with the AN/WSC-3 transceiver and designed primarily for shipboard installation. Depending upon requirements, one or two antennas may be installed to provide a view of the satellite at all times. The antenna is attached to a pedestal. This permits the antenna to rotate so that it is always in view of the satellite. The frequency band for receiving is 248 to 272 MHz and for transmitting is 292 to 312 MHz.

The AN/SRR-1 receiver system consists of up to four AS-2815/SSR-1 antennas (figure 2-28) with an amplifier-converter AM-6534/SSR-1 for each antenna. The antennas are used to receive satellite fleet broadcasts at frequencies of 240 to 315 MHz. The antenna and converters are mounted above deck so that at least one antenna is always in view of the satellite.

The newer satellite systems use the SHF band. One of the major advantages of these systems is that they use a very small parabolic antenna measuring only 12 inches in diameter.

A satellite antenna must be pointed at the satellite to communicate. We must first determine the azimuth (AZ) and elevation (EL) angles from a fixed location. Figure 2-29 illustrates how these angles are derived,

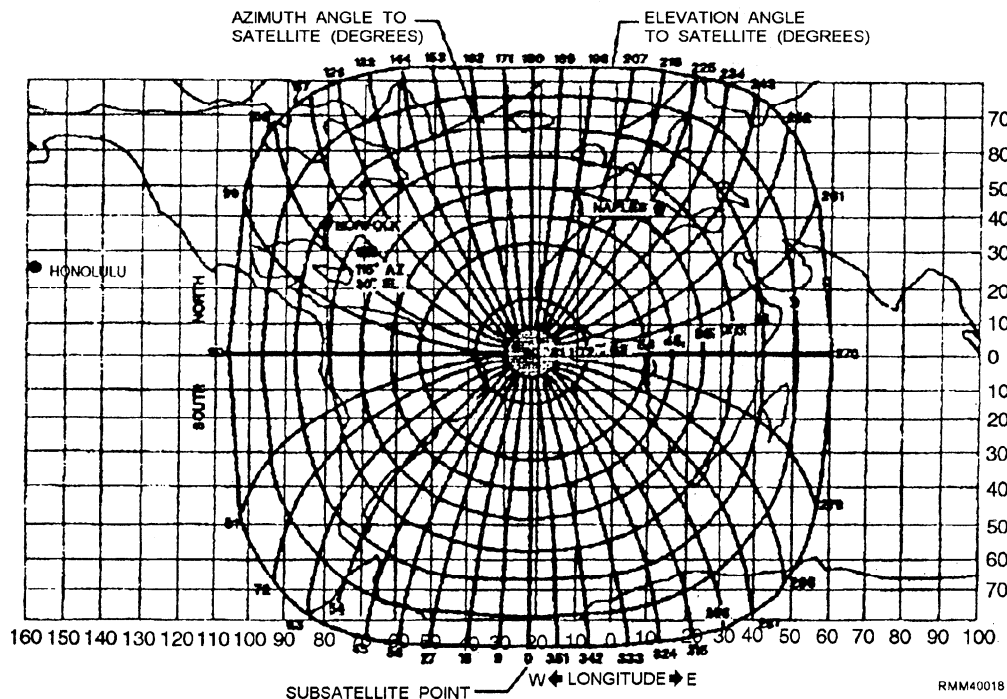


Figure 2-29.—Equatorial Satellite Antenna Pointing Guide.

using a pointing guide called the Equatorial Satellite Antenna Pointing Guide. This guide is normally available through the Navy Supply System.

The antenna pointing guide is a clear plastic overlay, which slides across a stationary map. It indicates AZ and EL angles in degrees to the satellite. The values obtained are useful to the operator in setting up the antenna control unit of a satellite system.

To use the guide, follow these procedures:

1. Center the overlay directly over the desired satellite position on the stationary map.
2. Mark the latitude and longitude of the ship on the plastic antenna pointing guide with a grease pencil.
3. Determine the approximate azimuth angle from the ship to the satellite.
4. Locate the closest dotted line radiating outward from the center of the graph on the overlay in relation to the grease dot representing the ship's location. This dotted line represents degrees of azimuth as printed on the end of the line. Some approximation will be required for ship positions not falling on the dotted line.
5. Determine the degrees of elevation by locating the solid concentric line closest to the ship's marked position. Again, approximation will be required for positions not falling directly on the solid elevation line. Degrees of elevation are marked on each concentric line.

**Example:** Assume that your ship is located at 30° north and 70° west. You want to access FLTSAT 8 at 23° west. When we apply the procedures above, we can determine an azimuth value of 115° and an elevation angle of 30°.

## RHOMBIC ANTENNA

The rhombic antenna, usually used at receiver sites, is a unidirectional antenna. This antenna consists of four long wires, positioned in a diamond shape. Horizontal rhombic antennas are the most commonly used antennas for point-to-point HF naval communications. The main disadvantage of this antenna is that it requires a relatively large area.

## MULTIWIRE RHOMBIC

A rhombic antenna improves in performance if each leg is made up of more than one wire. An improved

antenna, known as a curtain rhombic, uses three wires spaced 5 to 7 feet apart for each leg and connected to a common point (figure 2-30).

## SLEEVE ANTENNA

The sleeve antenna is used primarily as a receiving antenna. It is a broadband, vertically polarized, omnidirectional antenna. Its primary uses are in broadcast, ship-to-shore, and ground-to-air communications. Although originally developed for shore stations, there is a modified version for shipboard use. Figure 2-31 shows a sleeve antenna for shore stations.

Sleeve antennas are especially helpful in reducing the total number of conventional narrowband antennas that otherwise would be required to meet the requirements of shore stations. With the use of multicouplers, one sleeve antenna can serve several receivers operating over a wide range of frequencies. This feature also makes the sleeve antenna ideal for small antenna sites.

## CONICAL MONOPOLE ANTENNA

The conical monopole antenna (figure 2-32) is used in HF communications. It is a broadband, vertically polarized, compact omnidirectional antenna. This antenna is adaptable to ship-to-shore, broadcast, and ground-to-air communications. It is used both ashore and aboard ship.

When operating at frequencies near the lower limit of the HF band, the conical radiates in much the same manner as a regular vertical antenna. At the higher frequencies, the lower cone section radiates, and the top section pushes the signal out at a low angle as a sky wave. This low angle of radiation causes the sky wave to return to the Earth at great distances from the antenna.

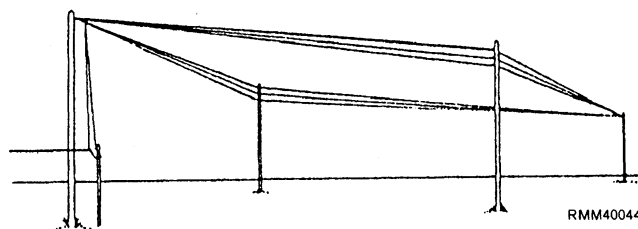


Figure 2-30.—Three-wire rhombic antenna.

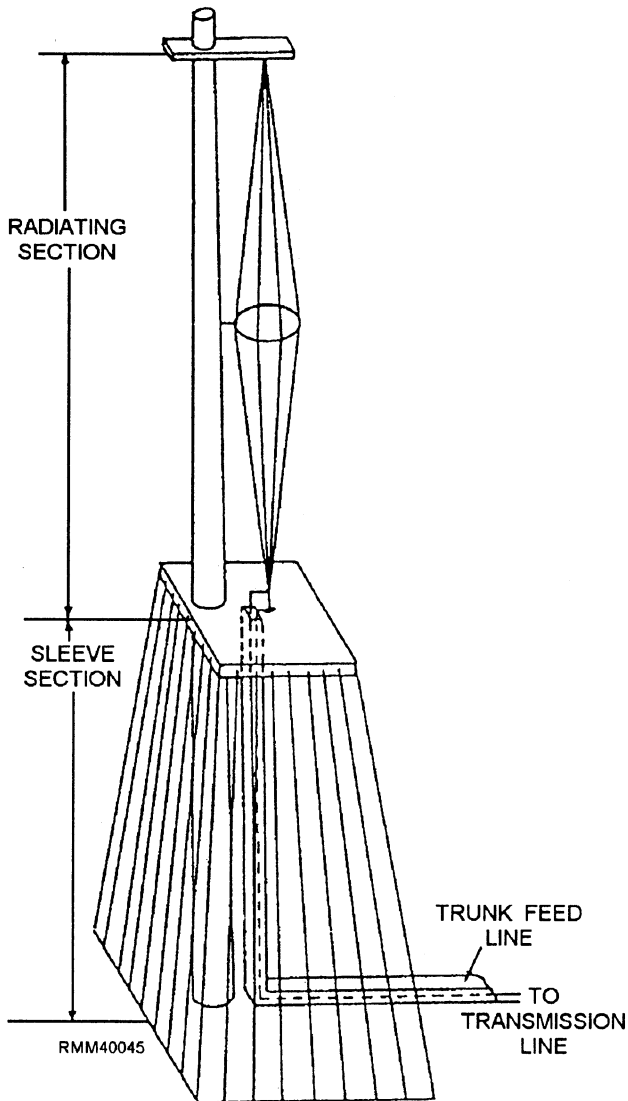


Figure 2-31.—Sleeve antenna (shore stations).

Therefore, this antenna is well suited for long-distance communications in the HF band.

### INVERTED CONE ANTENNA

The inverted cone antenna (figure 2-33) is vertically polarized, omnidirectional, and very broadband. It is used for HF communications in ship-to-shore, broadcast, and ground-to-air applications. The radial ground plane that forms the ground system for inverted cones is typical of the requirement for vertically polarized, ground-mounted antennas. The radial wires are one-quarter-wavelength long at the lowest designed frequency.

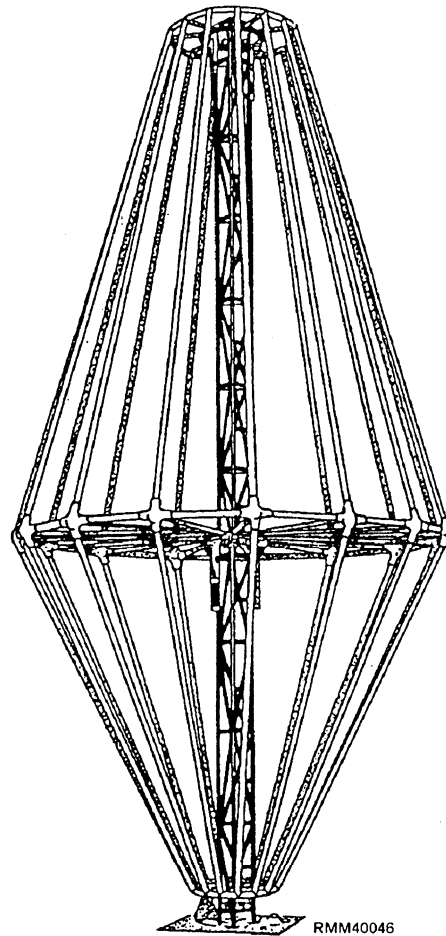


Figure 2-32.—Conical monopole antenna.

### LOG-PERIODIC ANTENNA

The log-periodic (LP) antenna operates over an extremely wide frequency range in the HF and VHF

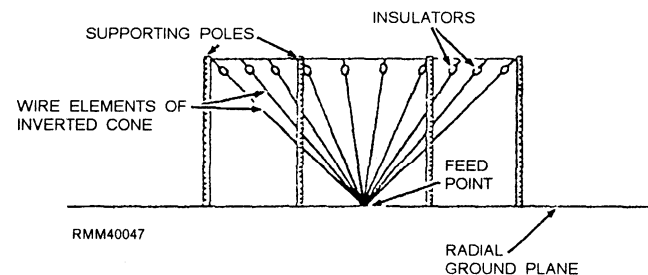


Figure 2-33.—Inverted cone antenna.

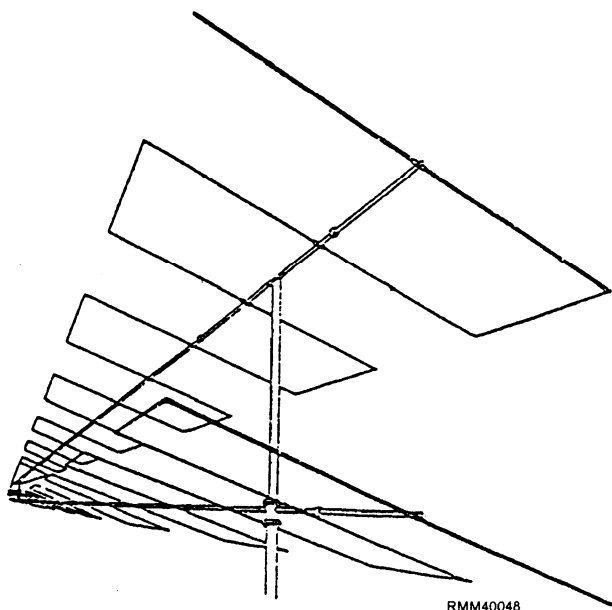


Figure 2-34.—Log-periodic antenna.

bands. Figure 2-34 shows a typical LP antenna designed for extremely broadbanded, VHF communications. The LP antenna can be mounted on steel towers or utility poles that incorporate rotating

mechanisms. This antenna is particularly useful where antenna area is limited. A rotatable LP antenna, known as an RLP antenna (figure 2-35), possesses essentially the same characteristics as the fixed LP antenna but has a different physical form. The RLP antenna is commonly used in ship-shore-ship and in point-to-point communications.

## EMERGENCY ANTENNAS

Damage to an antenna from heavy seas, violent winds, or enemy action can cause serious disruption of communications. Sections of a whip antenna can be carried away, insulators can be damaged, or a wire antenna can snap loose from its moorings or break. If loss or damage should happen when all available equipment is needed, you may have to rig, or assist in rigging, an emergency antenna to temporarily restore communications until the regular antenna can be repaired.

The simplest emergency antenna consists of a length of wire rope to which a high-voltage insulator is attached to one end and a heavy alligator clip, or lug, is soldered to the other. The end with the insulator is

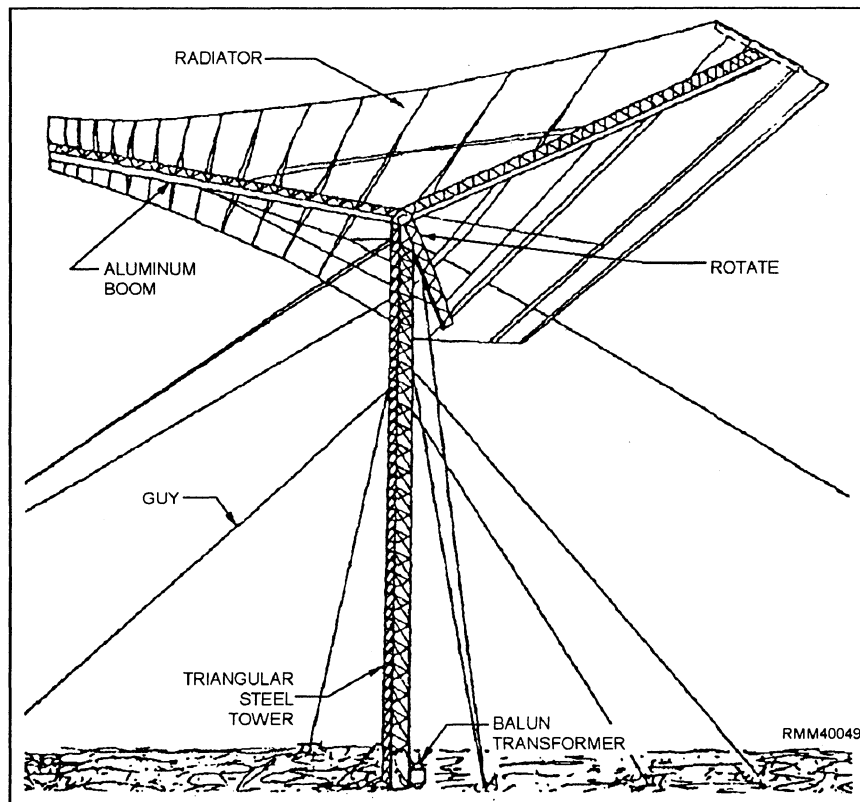


Figure 2-35.—Rotatable log-periodic antenna.

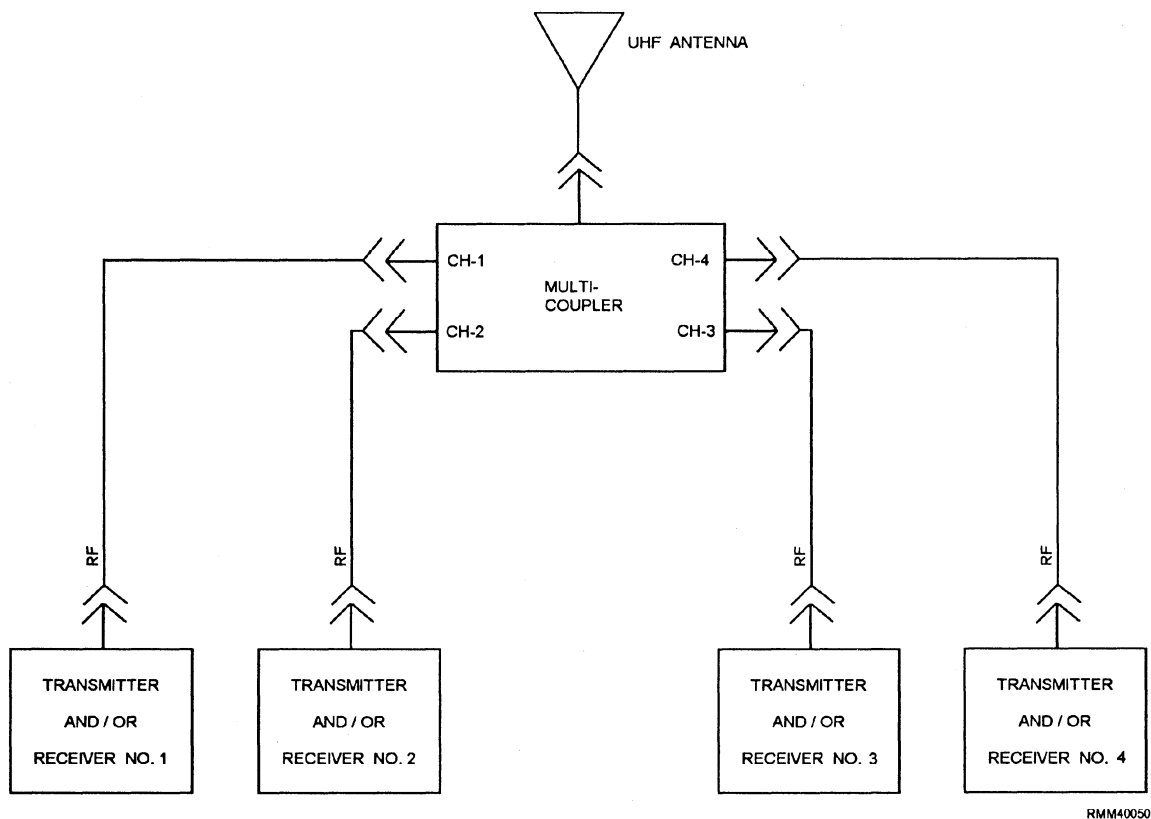


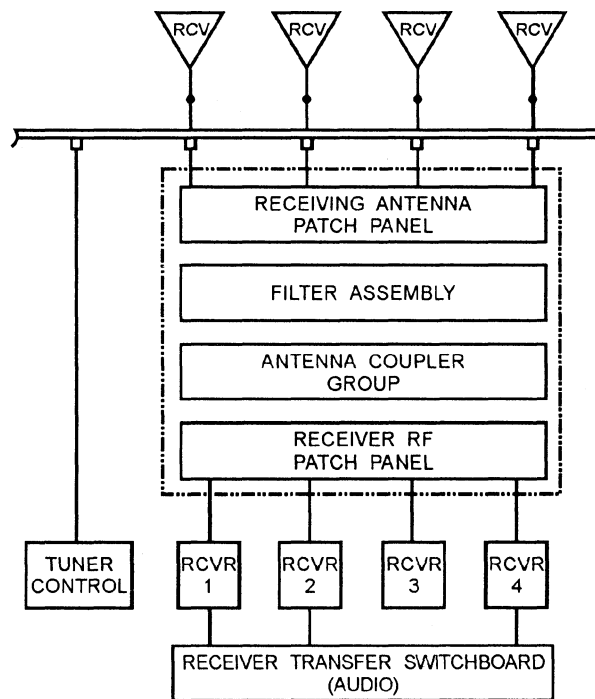
Figure 2-36.—Antenna multicoupler interconnection diagram.

RMM40050

hoisted to the nearest structure and secured. The end with the alligator clip (or lug) is attached to the equipment transmission line. To radiate effectively, the antenna must be sufficiently clear of all grounded objects.

### ANTENNA DISTRIBUTION SYSTEMS

In figure 2-36, we see a distribution system with one antenna that can be connected (patched) to one of several receivers or transmitters by way of a multicoupler. In this system, you can patch the antenna to only one receiver or transmitter at a time. However, some distribution systems are more complex, such as the one shown in figure 2-37. In this system, you can patch four antennas to four receivers, or you can patch one antenna to more than one receiver via the multicoupler. In either system, we need a way to connect the antenna to the receiver or transmitter that we want to use.



RMM40051

Figure 2-37.—Complex distribution system.

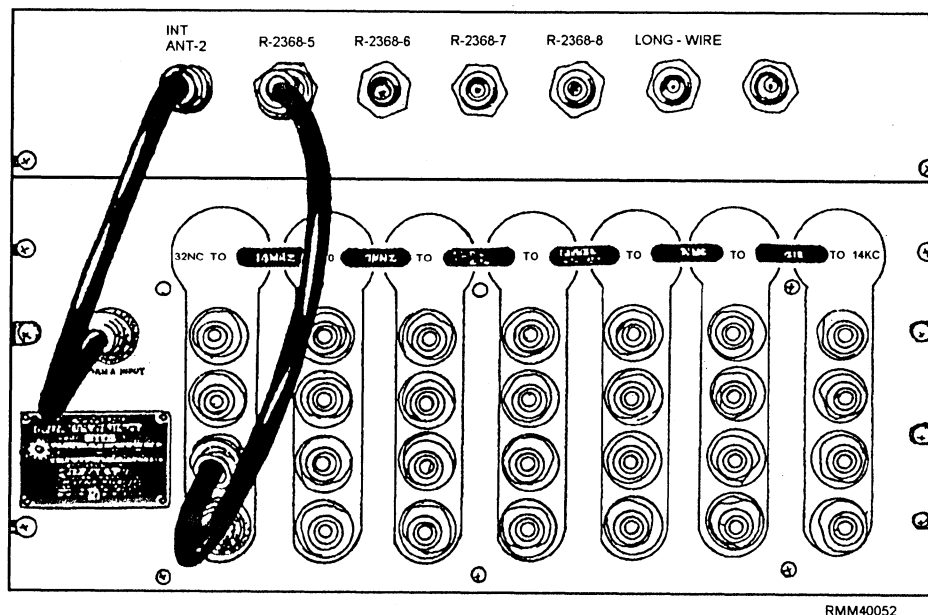


Figure 2-38.—AN/SRA-12 antenna filter patch panel with receiver antenna patch panel.

Figure 2-38 shows a receiver antenna filter patch panel, AN/SRA-12, with a receiver patch panel. The AN/SRA-12 provides seven radio-frequency channels in the 14-kHz to 32-MHz range. Any or all of these channels can be used independently of any other channel, or they can operate simultaneously.

On the receiver patch panel, a receiver is hardwired to each jack. With the use of patchcords, you can connect a receiver, tuned to a particular frequency, to the antenna by connecting the receiver to the proper jack on the AN/SRA-12. Figure 2-38 shows how the filter assembly is used in combination with other units to pass an RF signal from an antenna to one or more receivers.

**NOTE**

When patching, **YOU MUST ALWAYS INSERT THE END OF THE ANTENNA PATCH CORD TO THE RECEIVER JACK FIRST. THEN, YOU INSERT THE OTHER END OF THE PATCH CORD INTO THE LOWEST USABLE AN/SRA-12 JACK. TO UNPATCH, ALWAYS REMOVE THE PATCH CORD FROM THE RECEIVER JACK, THEN THE OTHER END FROM THE FREQUENCY FILTER JACK.** An easy way to remember this is always work the patching from the **top down.**

Transmitting antenna distribution systems perform the same functions as receiving distribution systems. Figure 2-39 shows a transmitter patch panel. These

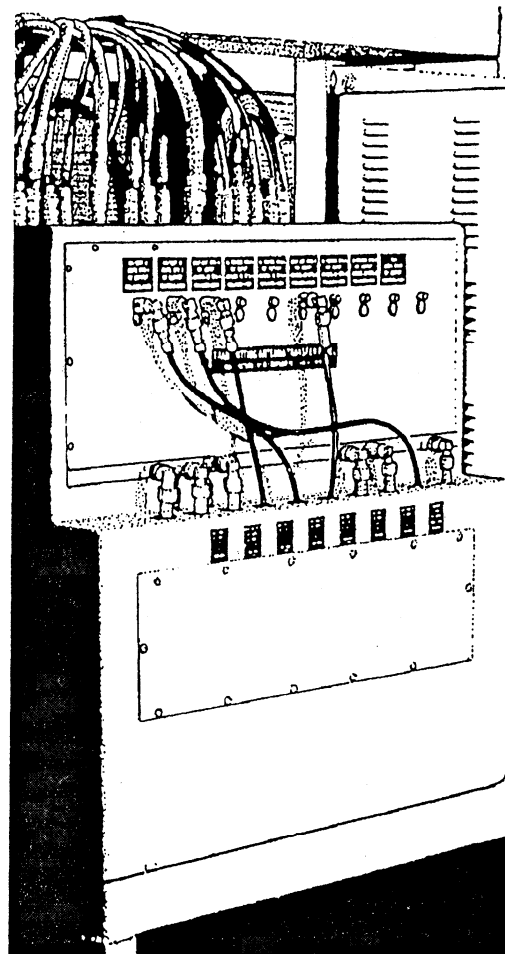


Figure 2-39.—Transmitter antenna patch panel.



transmitter patch panels are interlocked with the transmitter so that no open jack connection can be energized and no energized patch cord can be removed. This provides safety for both personnel and equipment.

## ANTENNA POSITIONING

Raise and lower antennas - raising and lowering physically of antennas is associated with flight, refueling or PMS operations. Extreme care should be taken that all moving parts are in correct operating conditions and the Officer of the Deck or Communications Watch Officers know prior to the physical movement of the antennas.

## USE DIRECTIONAL ANTENNAS

Reception is defined as: when an electromagnetic wave passes through a receiver antenna and induces a voltage in that antenna. Further detailed information on antennas, antenna use, wave propagation and wave generation can be found in NEETS MODULES 9, 10, and 17.

### Rotate For Optimum Reception

This is accomplished by both physical and mechanical means of moving the antenna(s) to properly align and tune the antenna.

### Align For Optimum Reception

Using the correct antenna location (by rotation) and the correct equipment for the system, you will bring the antenna into alignment and be ready for the final step, which is tuning.

### Tune For Optimum Reception

There are two objectives of antenna tuning: (1) to tune out the various impedances and (2) to match the length of the antenna to the frequency radiated at its characteristic impedance.

- **Impedance:** everything exhibits some impedance, Even a straight piece of copper wire 3 inches long will offer some resistance to current flow, however small. The characteristic impedance of this same piece of copper wire is its overall resistance to a signal.

The transmission line between an antenna and a transmitter has a certain amount of characteristic impedance. The antenna also has a certain amount of

characteristic impedance. This basic mismatch in impedance between the transmitter and the antenna makes antenna tuning necessary. Naturally, as transmitters, transmission lines, and antennas become more complex, antenna tuning becomes more critical.

- **Antenna length adjustment:** When we tune an antenna, we electrically (not physically) lengthen and shorten it. The radiation resistance varies as we vary the frequency of the transmitter and tune the antenna. The radiation resistance is never perfectly proportional to antenna length because of the effects of the antenna height above the ground and its location to nearby objects.

You will find that the better the ability of the receiver to reject unwanted signals, the better its selectivity, The degree of selection is determined by the sharpness of resonance to which the frequency-determining circuits have been engineered and tuned. You usually measure selectivity by taking a series of sensitivity readings. As you take the readings, you step the input signal along a band of frequencies above and below the circuit resonance of the receiver; for example, 100 kilohertz below to 100 kilohertz above the tuned frequency. As you approach the tuned frequency, the input level required to maintain a given output level will fall. As you pass the tuned frequency, the required input level will rise. Input voltage levels are then compared with frequency. They can be plotted on paper, or you may view them on an oscilloscope. They appear in the form of a response curve. The steepness of the response curve at the tuned frequency indicates the selectivity of the receiver, thus allowing for the optimum reception.

## RF SAFETY PRECAUTIONS

Although electromagnetic radiation from transmission lines and antennas is usually of insufficient strength to electrocute personnel, it can lead to other accidents and compound injuries. Voltages may be inducted in ungrounded metal objects, such as wire guys, wire cable (hawser), hand rails, or ladders, If you should come in contact with these objects, you could receive a shock or RF burn. This shock can cause you to jump or fall into nearby mechanical equipment or, when working aloft, to fall from an elevated work area. Take care to ensure that all transmission lines or antennas are deenergized before working near or on them.

Guys, cables, rails and ladders should be checked for RF shock dangers. Working aloft "chits" and safety harnesses should be used for your safety. Signing a

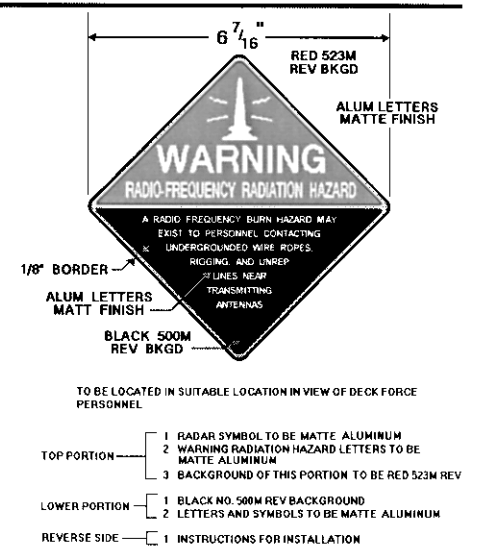
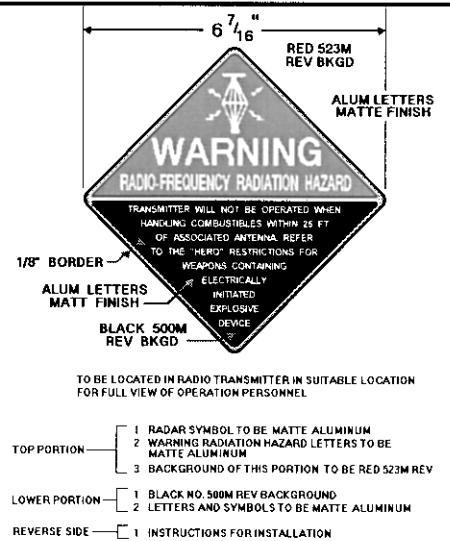
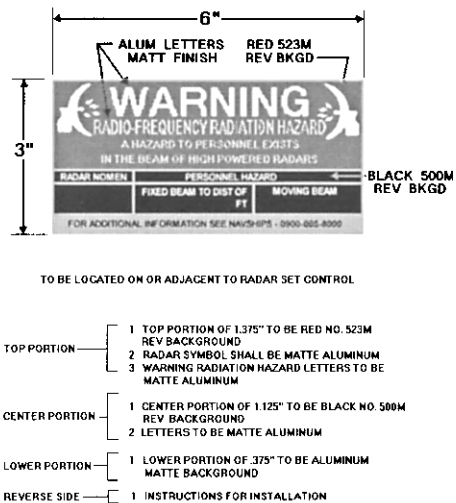
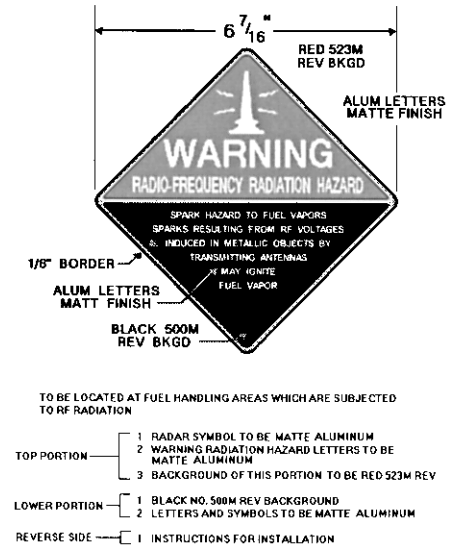
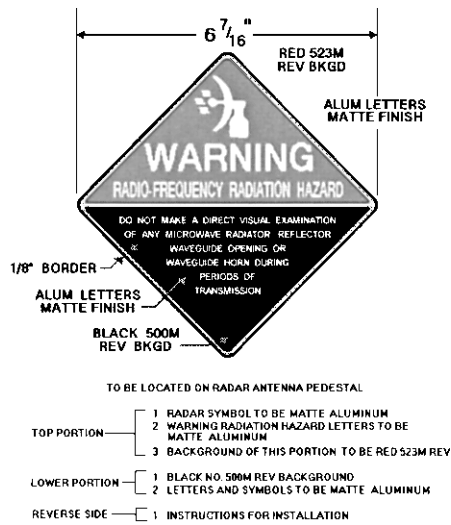


Figure 2-40.—Examples of RF radiation warning signs.

“working aloft chit” signifies that all equipment is in a nonradiating status (the equipment is not moving). The person who signs the chit should ensure that no RF danger exists in areas where personnel are working.

Nearby ships or parked aircraft are another source of RF energy that must be considered when checking work areas for safety. Combustible materials can be ignited and cause severe fires from arcs or heat generated by RF energy. RF radiation can detonate ordnance devices by inducing currents in the internal wiring of the device or in the external test equipment, or leads connected to the device.

You should always obey RF radiation warning signs and keep a safe distance from radiating antennas. The six types of warning signs for RF radiation hazard are shown in figure 2-40.

## **RF BURNS**

Close or direct contact with RF transmission lines or antennas may result in RF burns. These are usually deep, penetrating, third-degree burns. To heal properly, these burns must heal from the inside to the skin surface. To prevent infection, you must give proper medical attention to all RF burns, including the small “pinhole” burns. Petrolatum gauze can be used to cover burns temporarily before the injured person reports to medical facilities for further treatment.

## **DIELECTRIC HEATING**

Dielectric heating is the heating of an insulating material by placing it in a high frequency electric field. The heat results from internal losses during the rapid reversal of polarization of molecules in the dielectric material.

In the case of a person in an RF field, the body acts as a dielectric. If the power in the RF field exceeds 10 milliwatts per centimeter, a person in that field will have noticeable rise in body temperature. The eyes are highly susceptible to dielectric heating. For this reason, you should not look directly into devices radiating RF energy. The vital organs of the body are also susceptible to dielectric heating. For your own safety, you must not stand directly in the path of RF radiating devices.

## **PRECAUTIONS WHEN WORKING ALOFT**

Prior to going aloft, you must follow all NAVOSH and local requirements such as wearing a harness and a hard hat. You must have a safety observer and meet all other requirements.

When radio or radar antennas are energized by transmitters, you must not go aloft unless advance tests show that little or no danger exists. A casualty can occur from even a small spark drawn from a charged piece of metal or rigging. Although the spark itself may be harmless, the “surprise” may cause you to let go of the antenna involuntarily, and you may fall. There is also a shock hazard if nearby antennas are energized.

Rotating antennas also may cause you to fall when you are working aloft. Motor safety switches controlling the motion of rotating antennas must be tagged and locked opened before you go aloft near such antennas.

When working near a stack, you should draw and wear the recommended oxygen breathing apparatus. Among other toxic substances, stack gas contains carbon monoxide. Carbon monoxide is too unstable to build up to a high concentration in the open, but prolonged exposure to even small quantities is dangerous.

## **SUMMARY**

Naval communications using satellite and various antennas types must always be ready to shift from peacetime to wartime requirements. To this end, the diversity of fleet communication operations has given the Navy an expanded capability to meet ever-increasing command, control, and support requirements by use of satellites and assorted antennas.

Additionally, this variety of communications technology has increased the requirements for greater proficiency from all operating personnel. As a Radioman, you will be tasked with higher levels of performance in an increasingly technical Navy.



## APPENDIX I

# GLOSSARY

- A**
- ANTENNA**— A device used to radiate or receive radio waves.
- ANTENNA COUPLER**— A device used for impedance matching (tuning) between an antenna and a transmitter or receiver.
- ANTENNA RECIPROCALITY**— The ability of an antenna to both transmit and receive electromagnetic energy.
- ANTENNA TUNING**— The process where an antenna is electrically “matched” to the output frequency and impedance of the transmitter.
- ATTENUATION**— A deliberate reduction or an unintended loss in RF signal strength.
- B**
- BANDWIDTH**— Any section of the frequency spectrum occupied by specific signals.
- BIDIRECTIONAL ANTENNA**— An antenna that radiates in or receives most of its energy from only two directions.
- BLACK**— Cipher text or encrypted text or information
- C**
- CARRIER**— The unmodulated signal originally produced in the oscillator section of a transmitter.
- CARRIER FREQUENCY**— The final RF output without modulation. The assigned transmitter frequency.
- CHANNEL**— A carrier frequency assignment, usually with a fixed bandwidth.
- COMPLEX WAVE**— A transmitted radio signal composed of different frequencies.
- COUNTERPOISE**— The ground plane, or reflective surface, comprising an antenna’s reflected image at a given wavelength.
- CRITICAL FREQUENCY**— The highest transmitted frequency that can be propagated directly upward and still be bent, or “refracted,” back to Earth.
- CYCLE**— Two complete alternations of alternating current, or one complete revolution in any period of time, equal to 360°.
- D**
- DAMA (DEMAND ASSIGNED MULTIPLE ACCESS SUBSYSTEM)**— Subsystem that multiplexes several subsystems on one satellite channel.
- DIFFRACTION**— The bending of radio waves around the edges of a solid object or dense mass.
- DIRECTIONAL ANTENNA**— An antenna that radiates or receives radio waves more effectively in some directions than in others.
- DIRECTIVITY**— The sharpness or narrowness of an antenna’s radiation pattern in a given plan.
- DIRECT WAVE**— A radio signal that travels in a direct line-of-sight path from the transmitting antenna to the receiving antenna.
- DUMMY LOAD**— A nonradiating device used at the end of a transmission line in place of an antenna for tuning a transmitter. The dummy load converts transmitted energy into heat so that no energy is radiated outward or reflected back.
- E**
- EHF (EXTREMELY HIGH FREQUENCY)**— The band of frequencies from 30 GHz to 300 GHz.
- ELECTRIC FIELD**— A field produced as a result of a voltage charge on an antenna.
- ELECTROMAGNETIC ENERGY**— An RF source composed of both an electric and a magnetic field.
- ELECTROMAGNETIC WAVES**— Energy produced at the output of a transmitter; also called radio waves.
- F**
- FADING**— Variation, usually gradual, in the field strength of a radio signal that is caused by changes in the transmission path or medium.

**FEED POINT**— The point on an antenna at which the RF cable that carries the signal from the transmitter is connected.

**FOT (FREQUENCY OF OPTIMUM TRANSMISSION)**— The most reliable frequency for propagation at a specific time.

**FREQUENCY**— The number of complete cycles per unit of time.

**FREQUENCY DIVERSITY**— The method in which the information signal is transmitted and received on two separate radio frequencies simultaneously to take advantage of the fact that fading does not occur simultaneously on different frequencies.

**FSK (FREQUENCY-SHIFT KEYING)**— The process of shifting the incident carrier above and below the carrier frequency to correspond to the marks and spaces of a teleprinter signal.

## G

**GAIN**— An increase in signal strength.

**GIGAHERTZ (GHz)**— A unit of frequency equal to 1000 megahertz.

**GROUND**— A term used to denote a common electrical point of zero potential.

**GROUND-PLANE ANTENNA**— A type of antenna that uses a ground plane (a metallic surface) as a simulated ground to produce low-angle radiation.

## H

**HALF-WAVE DIPOLE ANTENNA**— A common type of half-wave antenna made from a straight piece of wire cut in half. Each half operates at a quarter of the wavelength. It is normally omnidirectional with no gain.

**HERTZ (Hz)**— A unit of frequency equal to one cycle per second.

**HERTZ ANTENNA**— An ungrounded half-wave antenna that is installed some distance above ground and positioned either vertically or horizontally.

**HF (HIGH FREQUENCY)**— The band of frequencies from 3MHz to 30MHz.

## I

**IMPEDANCE**— The total opposition to the flow of alternating current.

**INCIDENT WAVE**— The RF energy that travels from the transmitter to the antenna for radiation.

**INDUCTION FIELD**— The electromagnetic field produced around an antenna when current and voltage are present on the antenna.

## K

**KILOHERTZ (kHz)**— A unit of frequency equal to 1000 hertz.

## L

**LEASAT**— Leased satellite.

**LF (LOW FREQUENCY)**— The band of frequencies from 30kHz to 300kHz.

**LUF (LOWEST USABLE FREQUENCY)**— The lowest frequency that can be used at a specific time for ionospheric propagation of radio waves between two specified points.

## M

**MAGNETIC FIELD**— One of the fields produced when current flows through a conductor or an antenna.

**MARCONI ANTENNA**— A quarter-wave antenna that is operated with one end grounded; it is positioned perpendicular to the Earth.

**MEGAHERTZ (MHz)**— A unit of frequency equal to 1,000,000 hertz.

**MF (MEDIUM FREQUENCY)**— The band of frequencies from 300kHz to 3MHz.

**MIRROR IMAGE**— The part of the radiated signal of a quarter-wave antenna (Marconi antenna) appearing to come from an underground image of the real antenna. This image is also called ground reflection.

**MODULATED WAVE**— The wave that results after the information from the modulating signal is impressed onto the carrier signal. The wave that is transmitted

**MODULATION**— The process of adding, or superimposing, information on an RF carrier wave.

**MUF (MAXIMUM USABLE FREQUENCY)**— The highest operating frequency that can be used at a specific time for successful radio communications between two points.

## O

**OMNIDIRECTIONAL ANTENNA**— An antenna that radiates or receives equally well in all directions, except directly off the ends.

**OSCILLATOR**— An electrical circuit that generates alternating current at a particular frequency.

## P

**PARABOLIC ANTENNA**— An antenna that radiates its signal back into a large reflecting surface (called the dish) for radiation.

**PERIOD** (of a wave)— The time required to complete one cycle of a waveform.

**POLARIZATION** (of antennas)— The plane (horizontal or vertical) of the electric field as radiated from a transmitting antenna.

## R

**RADHAZ** (RADIATION HAZARD)— Electromagnetic radiation hazard generated from electronic equipment.

**RADIATION FIELD**— The electromagnetic field that radiates from an antenna and travels through space.

**RADIATION RESISTANCE**— The resistance that, if inserted in place of an antenna, would consume the same amount of power that is radiated by the antenna.

**RECIPROCITY**— See antenna reciprocity.

**RED**— Plain text or unencrypted information

**REFLECTED WAVE**— An electromagnetic wave that travels back toward the transmitter from the antenna because of a mismatch in impedance between the two.

**REFLECTION**— Occurs when a radio wave strikes the Earth's surface at some distance from the transmitting antenna and is returned upward toward the atmosphere.

**RF** (RADIO FREQUENCY)— A frequency in the range within which radio waves can be transmitted. Frequencies used for radio communication fall between 3kHz and 300GHz.

**RF ENERGY**— Radio frequency energy. Energy produced at the output of a transmitter.

## S

**SATELLITE COMMUNICATION** (SATCOM)— A type of worldwide, reliable, high-capacity, secure, and cost-effective telecommunications system utilizing satellites.

**SHF** (SUPER HIGH FREQUENCY)— The band of frequencies from 3 GHz to 30 GHz.

**SIGNAL**— Detectable transmitted energy that can be used to carry information.

**STANDING WAVES**— The stationary waves that buildup along an antenna during radiation.

**SWITCHBOARD**— Device that connects receiver outputs to numerous pieces of equipment.

**SWR** (STANDING-WAVE RATIO)— A term used to express the degree of resonance attained between the antenna and the transmission line when being tuned for transmission.

## T

**TRANSMISSION LINE**— A device designed to guide electrical or electromagnetic energy from one point to another.

## U

**UHF** (ULTRA HIGH FREQUENCY)— The band of frequencies from 300 MHz to 3 GHz.

**UNIDIRECTIONAL ANTENNA**— An antenna that radiates in only one direction.

## V

**VHF** (VERY HIGH FREQUENCY)— The band of frequencies from 30 MHz to 300 MHz.

**VLF** (VERY LOW FREQUENCY)— The band of frequencies from 3 kHz to 30 kHz.

## W

**WAVEFORM**— The shape of an electromagnetic wave.

**WAVELENGTH**— The distance traveled, in feet or meters, by a radio wave in the time required for one cycle.





## APPENDIX II

# GLOSSARY OF ACRONYMS AND ABBREVIATIONS

<b>A</b>		<b>FSB</b> — Fleet satellite broadcast.
<b>ASWIXS</b> — Antisubmarine Warfare Information Exchange Subsystem.		<b>FSK</b> — Frequency-shift keying.
<b>ASWOC</b> — Antisubmarine Warfare Operations Center.	<b>G</b>	
<b>AZ</b> — Azimuth.	<b>GHz</b> — Gigahertz.	
<b>C</b>	<b>H</b>	
<b>CAT</b> — Communications assistance team.	<b>HDX</b> — Half duplex.	
<b>CONUS</b> — Continental United States.	<b>HERO</b> — Hazardous electromagnetic radiation.	
<b>CUDIXS</b> — Common User Digital Information Exchange System.	<b>HF</b> — High frequency.	
<b>CW</b> — Continuous wave (Morse code).	<b>HPA</b> — High Power amplifier.	
<b>D</b>	<b>Hz</b> — Hertz.	
<b>DAMA</b> — Demand Assigned Multiple Access Subsystem.	<b>I</b>	
<b>dc</b> — Direct current.	<b>IF</b> — Intermediate frequency.	
<b>DSB</b> — Double-side band.	<b>K</b>	
<b>DSCS</b> — Defense Satellite Communications System.	<b>kHz</b> — Kilohertz.	
<b>E</b>	<b>L</b>	
<b>EHF</b> — Extremely high frequency.	<b>LEASAT</b> — Leased satellite.	
<b>EL</b> — Elevation	<b>LF</b> — Low frequency.	
<b>EMCON</b> — Emission control.	<b>LNA</b> — Low noise amplifier.	
<b>F</b>	<b>LOS</b> — Line of sight.	
<b>FDM</b> — Frequency division multiplexing.	<b>LP</b> — Log-periodic antenna.	
<b>FDMA</b> — Frequency division multiple access.	<b>LPI</b> — Low probability of intercept.	
<b>FDX</b> — Full duplex.	<b>LSTDMS</b> — Low speed time division multiplexer.	
<b>FFN</b> — Fleet flash net.	<b>LUF</b> — Lowest usable frequency.	
<b>FLTCINC</b> — Fleet Commander-in-Chief.	<b>M</b>	
<b>FLTSATCOM</b> — FM satellite communications.	<b>MHz</b> — Megahertz.	
<b>FOT</b> — Frequency of optimum transmission.	<b>MF</b> — Medium frequency.	

**MPA**— Medium power amplifier.

**MUF**— Maximum usable frequency.

## **N**

**NATO**— North Atlantic Treaty Organization.

**NAVCOMTELSTA**— Naval Computer and Telecommunications station.

**NAVMACS**— Naval Modular Automated Communications System.

**NCTAMS**— Naval Computer and Telecommunications Area Master Station.

**NCTS**— Naval Computer and Telecommunications stations.

**NECOS**— Net control station.

## **O**

**ORESTES**— Teleprinter subsystem.

**OTAR**— Over-the-air relay.

**OTAT**— Over-the-air transfer.

**OTC**— Officer in tactical command.

**OTCIXS**— Officer in Tactical Command Information Exchange Subsystem.

## **P**

**PRIS/S**— Primary ship-shore.

**PSK**— Phase shift keying.

## **R**

**RADHAZ**— Radiation hazard.

**RF**— Radio frequency.

**RLP**— Rotatable log-periodic antenna.

## **S**

**SAR**— Search and air rescue.

**SATCOM**— Satellite communication.

**SECVOX**— Secure voice.

**SHF**— Super high frequency.

**SSB**— Single-sideband.

**SSIXS**— Submarine Satellite Information Exchange Subsystem.

**SWR**— Standing-wave ratio.

## **T**

**TACINTEL**— Tactical intelligence system.

**TADIXS**— Tactical Data Information Exchange Subsystem.

**TDM**— Time division multiplexing.

**TDMA**— Time division multiple access.

## **U**

**UHF**— Ultra high frequency.

## **V**

**VHF**— Very high frequency.

**VSWR**— Voltage standing-wave ratio.

**VLF**— Very low frequency.

## APPENDIX III

# REFERENCES USED TO DEVELOP THIS TRAMAN

**NOTE:** The following references were current at the time this TRAMAN was published, but you should be sure you have the current editions.

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